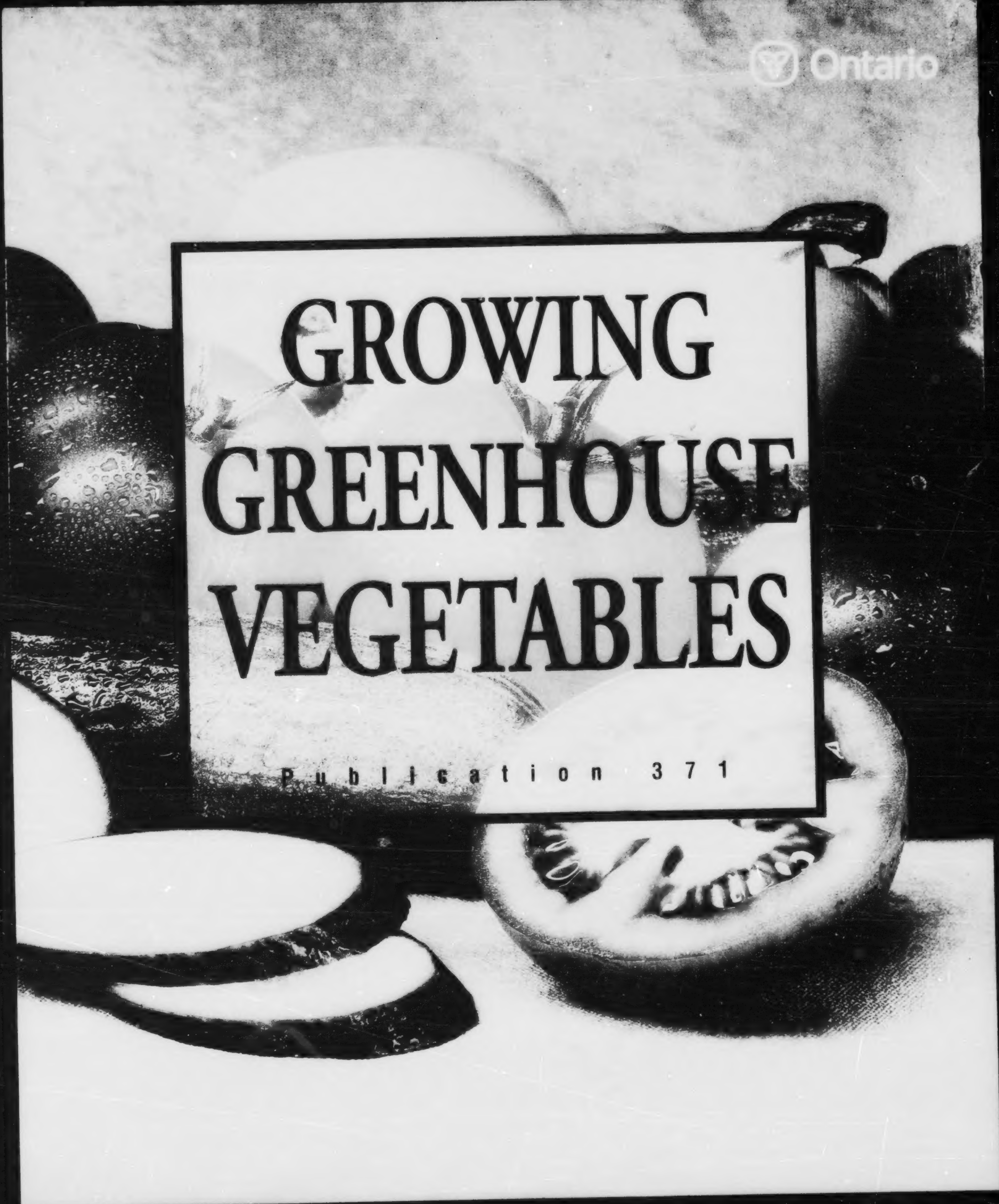


Ontario

GROWING GREENHOUSE VEGETABLES

Publication 371

MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

Each year the appropriate sub-committee of the Ontario Pest Management Research and Services Committee reviews the pesticides listed in this publication. To the best knowledge of the sub-committee, all of these pesticides were:

- federally registered
- reviewed by the Ontario Pesticides Advisory Committee (OPAC) and
- classified by the Ministry of the Environment as of November 2000

Discard old editions of this publication.

The information in this publication is general information only. All pesticides must be used in accordance with the product label and Regulation 914 under Ontario's *Pesticides Act.*

Pay close attention to all instructions and warnings on the pesticide label.

By printing this publication, the Ministry of Agriculture, Food and Rural Affairs does not offer any warranty or guarantee, nor does it assume any liability for any crop loss, animal loss, health, safety or environmental hazard caused by the use of a pesticide mentioned in this publication.

Policy Statement

In this publication, most recommendations list several pesticides that can be used for each pest discussed. In general, the least hazardous materials and those growers have used satisfactorily for years are listed first. More toxic pesticides and/or newer ones with less practical grower experience follow. In some cases, the most effective pesticides are highly toxic.

This publication lists a number of brand names of pesticides. This is for the grower's convenience only. It is neither an endorsement of the product nor a suggestion that similar products are ineffective.

Weather and other factors influence the effectiveness of pesticides and the likelihood of crop injury by pest control chemicals. Consult the product label and other information regarding compatibility with other materials, the effect of environmental conditions, and so on for the specific product being considered. Wettable or soluble powders (WP, SP, WDG or DG) are less likely to cause plant injury than liquid concentrates (EC, SC and F).

Health Canada has established maximum residue limits (MRLs) for pesticides. However, growers should be aware that processors or retailers may demand more restrictive limits. Growers should seek advice of their intended market as to which restrictions or limitations apply. Growers are also encouraged to keep accurate and up to date records on pesticide use in each crop.

Federal Registration and Provincial Classification

The Ministry of the Environment administers Ontario's *Pesticides Act* and Regulation 914.

All pesticides sold and used in Ontario must be:

- registered under the federal *Pest Control Products Act*, and
- classified under the provincial *Pesticides Act* by being placed in one of six schedules of the Ontario regulation.

Federal Registration

The Pest Management Regulatory Agency (PMRA) of Health Canada grants registration following an evaluation of scientific data to ensure that the product has merit and value; and the human health and environmental risks associated with its proposed use are acceptable.

1. **Full Registration**
   Pesticide registrations are normally granted for a period of five years, subject to renewal.

2. **Temporary Registration**
   Temporary registration may be granted for a period not to exceed one year, where the registrant agrees to produce additional scientific or technical information, or the pesticide is used for emergency control of a serious pest outbreak.

For more information on the federal registration system contact the PMRA at 1-800-267-6315 or www.hc-sc.ca/pmra-arla.

Provincial Classification

There are six classification schedules in Regulation 914. Pesticide products are classified based on their toxicity, environmental or health hazard, persistence of the active ingredient or its metabolites, concentration, and usage. This system regulates the distribution, availability and use of pesticide products in Ontario. For up-to-date information on the regulatory status of these or other pesticides contact the:

Ontario Pesticides Advisory Committee (OPAC),
2300 Yonge St., Suite 1203, Toronto, ON, M4P 1E4
Telephone (416) 314-9230 Fax (416) 314-9237
www.opac.gov.on.ca

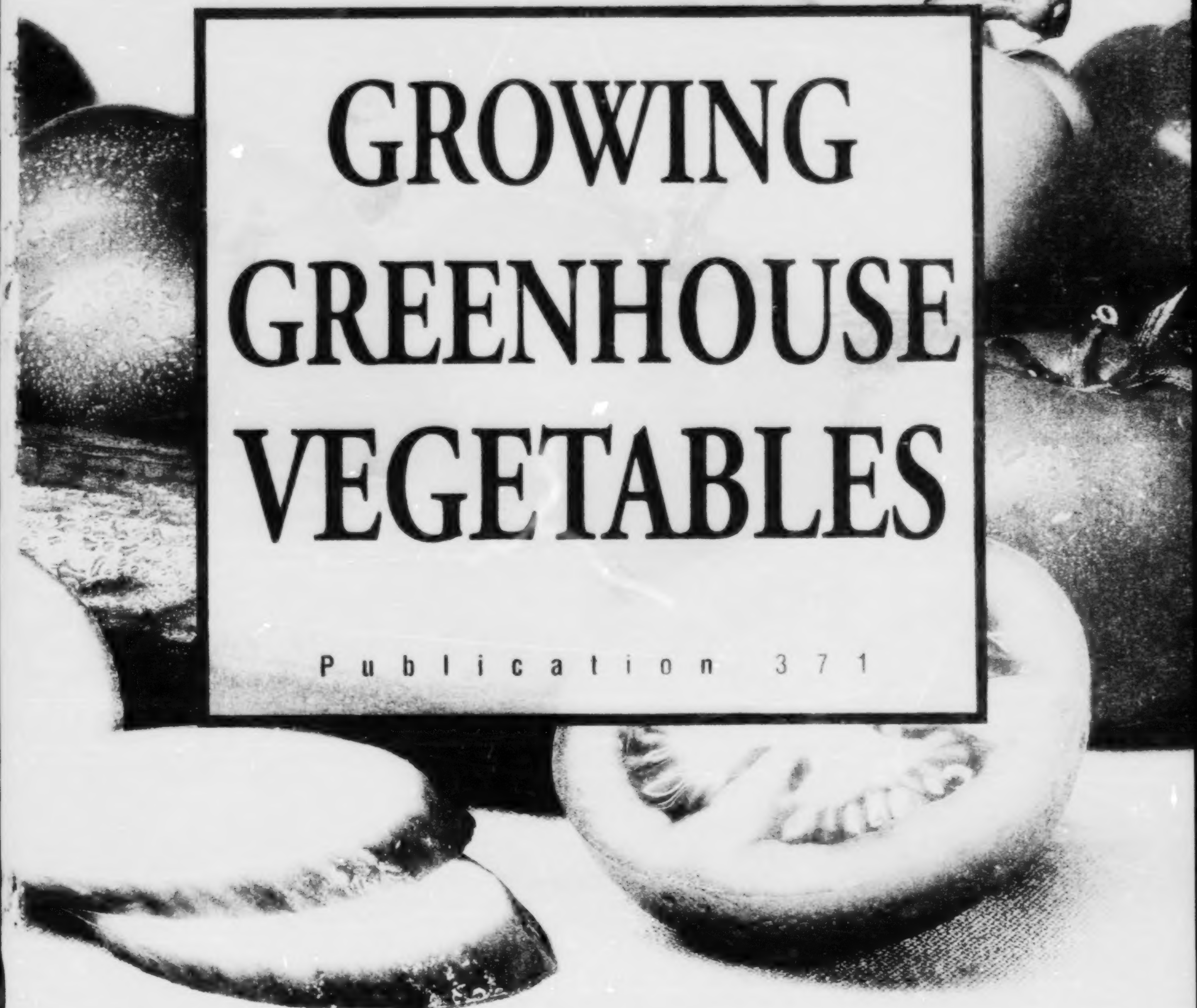
Farmer Certification

Regulation 914 of the *Pesticides Act* makes it mandatory for farmers to be certified through the Grower Pesticide Safety Course to buy and use Schedules 1, 2 or 5 pesticides on land they farm. There must be at least one Certified Grower for each farm operation.

As of January 2000, all assistants must receive formal pesticide safety training, recognized by the Ministry of the Environment, before they can use Schedule 2 or 5 pesticides under the supervision of a Certified Grower. This applies to all assistants — including family members, farm employees and seasonal workers.

For more information check the Ontario Pesticide Education Program Web site at www.ridgetownc.uoguelph.ca/opep/ or call 1-800-652-8573 or (519) 674-1580

Cette publication est aussi disponible en français.



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Publication 371

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Need technical and business information?

Contact the Agricultural Information Contact Centre at
1-877-424-1300
or ag.info@omafra.gov.on.ca

Looking for greenhouse production information on the Internet?

www.gov.on.ca/omafra/english/crops/hort/greenhouse.html

It's one-stop shopping for factsheets, articles and photos regarding the production and maintenance of greenhouse crops.

Acknowledgements
This book was written in conjuction with Ontario Greenhouse Vegetable Growers.
Cover photo courtesy of Ontario Greenhouse Vegetable Growers.

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1. Using Pesticides Safely

General Precautions

- Before opening pesticide containers, always read the label and follow all precautions and directions.

- Keep a record of the common names of all the pesticides you handle, especially those listed as hazardous in this publication. Other members of your family need to know about this list in case there is an accident.

- Never smoke, chew tobacco, or eat while handling or applying pesticides. Do not carry tobacco or food in clothes worn while spraying.

- Change your clothes and wash before eating.

- When handling and mixing pesticide concentrates, rinsing empty containers, or repairing leaks, wear a full set of protective clothing. This includes a waterproof cap, coveralls, impervious gloves, boots, and safety goggles.

- If you are using highly or extremely toxic pesticides or very dusty formulations, wear a respirator. If you are handling dusty formulations, wear a dust mask. If you are handling volatiles or gases, you must wear a respirator. If these gases are highly dangerous or you are handling them in an enclosed space, you may need a self-contained breathing apparatus. Make sure you follow the specific instructions on the pesticide label.

- When you draw water from wells, ponds, streams, or other sources, use an anti-backflow device to prevent back-siphoning.

- Mix pesticide at least 50 m from wells, ponds, or streams. Triple or pressure rinse the empty container and add the rinse water to the tank. Only mix enough solution to do the spray job.

- When you have finished loading and mixing, wash down your gloves and boots with clean water before removing them.

Always read the label and follow the instructions on it.

- During application, tractor cab with charcoal filter gives adequate protection against exposure.

- Wear impervious gloves, boots, coveralls, and cap when tending to system failures.

- When using air blast and mist blowers or when in tractors without cabs, wear waterproof suits and caps and impervious gloves and boots. When applying fumigants in the greenhouse, have a respirator for dealing with equipment problems or in case inadequate sealing in the soil/ground allows the fumigant to escape.

- When the spray operation is done, bathe or shower to remove pesticide deposits on your skin. Do not handle anything in your home before you bathe.

Preventing Farm Water Supply Contamination

Pesticides can contaminate well, pond, and surface water. In fact, it is an offence to contaminate surface waters with pesticides. Taking the following steps will help prevent contamination:

- Keep pesticide concentrates above the flood plain in locked storage.

- After emptying, triple or pressure rinse, crush, and dispose of containers.

- Return empty plastic or metal containers to a dealer who participates in the container-recycling program.

- Empty bags may be burned or disposed of at a landfill site.

- Mix concentrates and water at least 50 m away from any water supply.

- Use buffer zones and berms to avoid contaminating surface water, wells, ponds, and streams.

- Do not use drinking water sources to fill spray equipment. If you fill your tank from a well, lake, river, or other surface water source, you must use an anti-backflow device.

- When applying pesticides around the greenhouse:

  — do not spray within 10 m of shallow wells or 5–10 m of other water supplies in ideal weather and farther away if there is any air movement
  — stop spraying when wind velocity reaches 10 km/hr.

If An Accident Occurs

1. **Always protect yourself from injury first.** Don't become another victim. Always put on protective clothing and equipment before you enter a contaminated area or handle a contaminated victim.

   If clothing becomes wet with a pesticide, remove it immediately, wash/bathe yourself and put on fresh clothes.

2. Check to see if the victim is breathing.

   If the victim is not breathing:
   — Straighten the victim's airway and check for breaths.
   — If the victim does not begin to breathe, administer artificial respiration until the victim begins to breathe on his/her own.
   — Do not contaminate yourself, especially if the victim has pesticide or vomit around his face or mouth. Use a face shield airway with a one way valve. Do not breathe the exhaled air from the victim.
   — Perform CPR if the victim's pulse disappears. You should only perform CPR if you are trained to do so.

   If the victim is breathing, but unconscious:

   — Place the victim in the recovery position (on the side with the head turned slightly to one side). If the victim vomits, try to keep the airway clear.

3. Stop the exposure to the pesticide. Move the victim away from the contaminated area. Remove all contaminated clothing. Use soap and water to wash any skin exposed to the pesticide.

4. Check the Four Basic Facts
   — **Identify the pesticide**. Look for the label, container or leftover pesticide.
   — **Quantity** — How much product was the victim exposed to?
   — **Route of entry** — How did the pesticide enter the body? Did it enter through the mouth, skin/eyes or lungs?
   — **Time period** — How much time has passed since the victim was exposed to the pesticide, and how long was the exposure? Were the symptoms immediate or did the poisoning occur as a result of using the pesticide over a longer period of time?

Don't waste time. If you can't answer these questions quickly, be ready to tell emergency personnel whatever you can.

5. Call an ambulance or the Poison Information Centre.

6. Start the First Aid treatment appropriate for the route of entry.

7. Make sure the patient gets medical attention. First aid is not a substitute for professional medical help.

Personal Clean-up

- Wash your gloves, boots, and respirator before removing them.
- Take off your clothing, including underclothes, immediately and wash contaminated skin thoroughly with soap and water.
- Soak clothes immediately and double launder them as soon as possible.
- If the spill was serious, place the clothes in a plastic bag and dispose of them in a safe manner.
- Wash your gloves, boots, and respirator again.
- If clothing becomes wet with a pesticide, remove it immediately, wash, and put on fresh clothes.
- If symptoms of illness occur during or shortly after handling a pesticide, go to a hospital. Take your list of common-name chemicals with you. (See *Emergency Procedures for Pesticide Poisoning* on the inside back cover.)

If a pesticide gets on your clothes, always remove these clothes immediately!

- Clean up any pesticide spills immediately.
- In the case of minor spills, use dry soil or other absorbent material such as kitty litter to remove excess liquid. Sweep up powders and granulars.
- Contaminated soil and sweepings should be spread over a large area of bare soil to facilitate rapid degradation.
- Make sure you are adequately protected when cleaning up the spill.
- For information on preventing spills, see the OMAFRA factsheet, *Ways to Avoid Pesticide Spills*, Order No. 96-025.
- In the case of a major pesticide spill, you must notify the Ministry of the Environment, Spills Action Centre, 5775 Yonge St., Suite 1005, Toronto, Ontario, M2M 4J1, 416-325-3000 or 1-800-268-6060.
- If a well becomes contaminated, follow the clean-up instructions in OMAFRA Factsheet, *Pesticide Contamination of Farm Water Supplies*, Order No 00-099. (See inside front cover for information on how to obtain factsheets.).

Emergency procedures for pesticide poisoning and important first-aid information appear on the inside back cover of this book.

Relative Toxicity to Applicator

Toxicity Definitions

Lethal Dose 50% (LD_{50})

The dose that, when administered, will kill 50% of the test animals within a stated period.

Acute Toxicity

Immediate adverse effects from a single or short period of exposure to a substance by the oral, dermal, or inhalation route.

High Acute Toxicity

These pesticides are extremely dangerous if handled carelessly. The acute oral LD_{50} is less than 50 mg/kg of body weight, and the acute dermal LD_{50} is less than 200 mg/kg body weight.

- These pesticides can be fatal if you take less than 0.1 to 3.0 mL (1 drop to half a teaspoon).
- These pesticides are labeled with the skull and crossbones in a stop sign.
- You must use a respirator and eye protection along with all other protective clothing when using these products.

Moderate Acute Toxicity

These pesticides are dangerous if handled carelessly. The acute oral LD_{50} is 50–500 mg/kg of body weight, and the acute dermal LD_{50} is 200–2,000 mg/kg body weight.

- These pesticides can be fatal if you take 3–30 mL (half a teaspoon to 2 tablespoons).
- These pesticides are labeled with the skull and crossbones on a stop sign.
- You should wear a respirator when handling these concentrates.

Low Acute Toxicity

These pesticides are not fatal unless deliberately ingested in amounts of over 30 mL (1 oz.). The acute oral LD_{50} is greater than 500 mg/kg body weight, and the acute dermal LD_{50} is greater than 2,000 mg/kg body weight.

- You should handle them with caution.
- You must wear protective clothing.
- You should wear safety goggles, and, if using these products in a confined space, you should use a respirator.

Chronic Toxicity

Adverse effects resulting from repeated exposure to a substance over an extended period.

It is not possible to assess chronic toxicity of a pesticide in the same way an LD_{50} is used to determine acute toxicity. Instead, a number of tests performed on animals help predict whether a pesticide may cause long-term effects.

- Animals are examined for many toxic effects such as the production of tumors or abnormalities.
- Using protective clothing and equipment will help reduce exposure and the risk of chronic effects.

Entering Treated Areas

Workers may be poisoned if they enter greenhouses without protective clothing and equipment too soon after pesticides have been applied. Such poisoning can result from handling treated plants or from inhaling pesticide vapours. The list below shows a specific minimum interval that you must observe between applying a pesticide and working in the crop without protective equipment:

Avid	Do not re-enter treated area until residues have dried
Exotherm Termil	Greenhouse should be well-ventilated for at least 2 hr before re-entering
Nova	Do not re-enter treated area until residues have dried
Previcur	Do not re-enter treated area for at least 12 hr after application
Parathion	Ventilate greenhouse thoroughly after fumigation

Blood Tests for People Applying Pesticides

Organophosphorus and *carbamate* pesticides can inactivate serum and red blood cholinesterase levels. If cholinesterase activity falls below a critical level, poisoning can result. Symptoms include fatigue, dizziness, nausea, trembling, blurred vision, and difficulty breathing.

If you use the pesticide groups listed below, have your family doctor check your cholinesterase levels. To be of value, the tests should be started before you use these pesticides — the normal level can vary considerably, making it difficult to assess the degree of suppression. In this publication, see Table 1-1 below for insecticides of primary concern.

TABLE 1–1. Organophosphates and Carbamates Registered for Greenhouse Vegetables

Organophosphates	Carbamates
Basudin or Diazinon	Thiodan
Dibrom	Previcur
Malathion	
Parathion	

Protective Outdoor Clothing and Equipment

Why Use Personal Protection?

Pesticide formulations vary in toxicity from slightly poisonous to extremely poisonous. Exposure occurs once the pesticide is removed from the container. The toxicity of the pesticide and exposure to the user create a hazard. Both can be reduced—toxicity by dilution and exposure by protective clothing.

You can reduce the hazards of spraying, and thus the risk of poisoning. Wearing protective clothing and equipment reduces the risk.

Reducing Exposure

Exposure can be through skin, eyes, mouth, or nose. About 80%–85% of the exposure in most spray operations is during mixing and loading concentrate. Application usually accounts for 15%–20% of the exposure. Skin exposure is usually 90%–100% of the total exposure. About 70% of this is by way of the hands and forearms and 30% involves the rest of the body. Inhalation (nose and mouth) exposure is normally 0.1% but rises to 5%–10% with mist blowers and air blast sprayers.

Stage	Risk
Handling and mixing concentrate	very high
Rinsing empty containers	high
Applying outdoors	low–high
Applying indoors	medium–very high
Cleaning up, rinsing equipment	medium–high
Entering treated area within 48 hours	low–very high

Protective Clothing

- To reduce skin (dermal) exposure, wear impervious gloves. Always refer to the product label. Unless the label says otherwise, use neoprene or nitrile gloves. Always wear waterproof boots, along with coveralls, apron or spray suits, and a waterproof cap.

- Coveralls can be reusable or disposable. Reusable coveralls are normally cotton or polyester and should be tightly woven. It's easier for pesticides to penetrate polyester than cotton. Disposable coveralls are polyethylene and may be laundered several times. Spray suits should be used in highly hazardous conditions, such as with mist blowers and air blast machines.

- Protect your eyes with safety goggles when working with any pesticide concentrate.

Respirators

- Use respirators when handling pesticides with labels that call for respiratory protection and that carry the warning stop sign with skull and crossbones.

- Use respirators when spraying any pesticide rated as high toxicity or when applying any liquefied gas.

- Respirators are available as air purifiers or self-contained units and come in a wide range of shapes and sizes. Consult the label and your nearest safety supply company for advice.

- Make sure the cartridge or canister you use has a safety-approved sticker with the letters NIOSH (National Institute for Occupational Safety and Health) on it.

Washing Protective Clothing

- To keep your protective clothing and equipment functional, clean it thoroughly.

- Never let children or pets be exposed to contaminated clothing or equipment.

- Launder clothing promptly, wash and store other personal protection items, and rinse spray equipment before storing it away to prevent children playing with it.

Fabric Clothing

- Wear nitrile or neoprene gloves when handling severely contaminated clothing.

- If fabric is saturated with the concentrate of a highly toxic pesticide, throw it out.

- Remove the clothing carefully, immediately put it in a plastic bag, and dispose of it in a safe manner.

For a normal spray operation, follow these guidelines, preferably twice a day, but at least at the end of the work day:

- Rinse clothing outdoors

- Soak and wash clothing separately

- Soak clothes, with detergent, in a container such as a large bucket or tub; or use the prewash cycle of an automatic washer along with detergent. Pre-wash, solvent-based products work on EC formulations

- Wash only a few garments at a time

- Use heavy-duty liquid detergents

- Use hot water, the highest water level, and a hot super-wash cycle

- Do 2 complete wash cycles, each with a double rinse

- After washing, run the empty washer through another wash cycle with detergent to decontaminate the washing machine

- Hang the clothes to dry, outside if possible, to avoid a potential build-up of pesticide residue in the dryer

Rubber, Vinyl, or Plastic Boots and Gloves

- To avoid getting pesticide on your hands, wash the outside of your boots and gloves with detergent and water before taking them off.

- After removing boots and gloves, wash them inside and out with detergent and water, rinse them thoroughly, and dry them in a well-ventilated area.

Chemical-Resistant Clothing, Goggles, and Face Mask

- Wash plastic or rubber clothing and equipment with detergent and water and rinse thoroughly.

- Dry in a well-ventilated area.

Respirators

- Discard cartridges, canisters, and filter pads when breathing becomes difficult, when you notice a pesticide odour, or at the interval set by the manufacturer.

- Make a note of the date the cartridge is first used.

- Remove cartridges and filter pads from the face piece and store them in clean, sealed plastic bags.

- Wash the face piece in detergent and water, rinse it thoroughly, and dry it in a well-ventilated area.

- Never use alcohol or other solvents for cleaning, as they will damage the rubber and plastic.

Protective Devices for Use in Enclosed Areas

Canister Gas Masks

- Canister gas masks are effective for protection against certain harmful gases, vapours, and particulate matter.

- They are generally suitable for ventilated areas not subject to rapid change, but should never be used in confined spaces where oxygen deficiency and high gas concentrations may occur.

Self-Contained Breathing Apparatus

- Air purifying devices do not work in confined spaces where gas concentrations are unusually high. The lack of oxygen can prove fatal. Under these conditions, you need an air supply provided by a self-contained breathing apparatus (e.g., a Scott Air Pack).

- Substances that produce hydrogen cyanide, methyl bromide, chloropicrin, or phosphine can cause high gas concentrations and oxygen deficiency, as can smoke generators, foggers using highly toxic pesticides, and some volatile sprays.

Other Protective Clothing

- Wear other protective clothing in keeping with requirements listed on the pesticide label.

Working Conditions

- Use canister gas masks when the surrounding air contains low concentrations of toxic gases, vapours, or particulate matter derived from soil-drench, granular, dust, or foliar spray applications. Pesticides applied in this manner usually have moderate to low toxicity.

- You must use a self-contained breathing apparatus (e.g., a Scott Air Pack) when applying highly toxic pesticides. These can produce high concentrations of toxic gases, vapours, or particulate matter, and a lack of oxygen, especially in an enclosed space (e.g., spraying a greenhouse).

- Contact your safety supply company for their recommendation. See Table 1-2.

Space Fumigants and Insecticide Smokes

Learn about the health hazards and toxic properties of the pesticide you're using. Consult the product label, Material Safety Data Sheets (MSDS), or manufacturer for this information. Check the company Web sites for MSDS information.

- When using fumigants or insecticide smoke generators, wear protective clothing to prevent skin and inhalation exposure. During and after treatment, lock the greenhouse and building, and post warning signs.

- Follow instructions on the product label regarding aeration of treated greenhouse and buildings, or other enclosed areas before letting anyone enter.

Using Fumigants

- An agriculturalist using methyl bromide plus chloropicrin or aluminum phosphide to fumigate greenhouses must obtain a permit issued under the *Pesticides Act*.

- To apply for a permit, contact the local pesticides officer at the Ministry of the Environment.

- As a safety precaution, have someone else who is wearing personal protective equipment help with the fumigation.

- Always consult the product label.

- When handling methyl bromide, do not wear gloves because these will trap gas next to the skin. You must wear a full-face respirator with organic vapour canister or positive pressure breathing apparatus.

- When handling aluminum phosphide, use cotton gloves and wear a full-face mask respirator with an acid gas canister.

TABLE 1–2. Safety Supply Houses

Made by	Available from	Branches	Telephone
Optical	Aearo Canada Ltd., 7115 Tomken Road, Mississauga, ON L5S 1X7	Mississauga, Gravenhurst	905-795-0700 888-387-9681
H.S. Cover Survivair	Levitt-Safety Ltd., 2872 Bristol Circle, Oakville, ON L6H 5T5	Kitchener, London, Oakville, Ottawa, Sarnia, Stoney Creek, Sudbury, Thunder Bay	905-829-3299 888-453-8488
Kasco Helmets	The St. George Co., P.O. Box 430 20 Consolidated Drive Paris, ON N3L 3T5	www.thestgeorgeco.com	519-442-2046 800-461-4299
Mine Safety Appliances	MSA Canada Inc., 148 Norfinch Drive, Toronto, ON M3N 1X8		416-667-9400 800-267-0672
3M Canada Inc. Occupational and Environmental Safety Products	A wide range of distributors. Contact P. O. Box 5757, London, ON N6A 4T1		519-451-2500
North Safety Products Ltd.	26 Dansk Court, Toronto, ON M9W 5V8		416-675-2810 800-268-6925
Racal Airstream, Scott, Willson	Acklands-Grainger Inc. 90 West Beaver Creek Rd. Richmond Hill L4B 1E7	Hamilton, Kingston, Kitchener, London, St. Catharines, Sarnia, South Porcupine, Thunder Bay, Windsor	800-387-5744
Medical Safety First Aid	Kit Care Corp., 91 Kelfield St., Unit 6, Toronto, ON M9W 5A3	Kitchener, London, Orillia, Ottawa, St. Catharines, Stoney Creek	416-243-3030

Many of these companies also have dealer outlets. For details, contact the supply company.

- For more information, obtain Methyl Bromide Structure Fumigation Procedures and Aluminum Phosphide Structure Fumigation Procedures from the Ministry of the Environment.

Chemical Fumigants

Chemical fumigants such as Basamid, methyl bromide, Telone, Vapam, and Vorlex can be used for pasteurizing soil for potting or in greenhouse beds or benches. Each of these fumigants has a specific rate and activity against soilborne insects, diseases, nematodes, and weeds. Note that some formulations may be less effective against certain types of pests — always read the manufacturer's label. Be sure to protect crops in adjoining beds or benches from accidental exposure to escaped fumes.

Fumigants listed below are effective as preplanting treatments for greenhouse soil beds. The amounts shown are for use on 100 m^2:

TABLE 1–3. Control of Nematodes

Telone IIB	2.0 L
Telone C-17	2.0 L
Vorlex Plus	2.5 L

TABLE 1–4. Control of Nematodes, Fungi, Insects and Some Bacteria

Basamid (granular)	3.25–5 kg worked in to a depth of 15–23 cm
Vapam (liquid)	10 L
Vorlex Plus (liquid)	6 L
Methyl bromide/ Chloropicrin	Pressurized cans 98%/2%: 7.5–10 kg
	Injectable 68%/31.8%: 2.5–3.65 kg

Storing Pesticides

- The *Ontario Pesticides Act* and *Regulation 914* require that all pesticides be kept out of the reach of children, irresponsible persons, pets, and livestock. They should be stored in a locked facility away from food and feed.

- Herbicides should be stored separately from other pesticides to avoid contamination.

- Always store pesticides in their original containers and keep them tightly closed.

- Never put pesticides in unmarked containers.

- In areas where flooding has been frequent, you must store fertilizers and pesticides above the known high-water mark.

- Contamination of water by these chemicals has led to serious health problems for humans and domestic animals as well as fish and wildlife.

- See also the OMAFRA factsheet, *Pesticide Handling Facilities*, Order No. 94-037.

Schedule 1, 2, and 5 Pesticides

- Schedule 1, 2, and 5 pesticides must be stored in a locked facility that is ventilated to the outside.

- A sign that says "CHEMICAL STORAGE WARNING — AUTHORIZED PERSONNEL ONLY" in block capitals must be fixed to the outside of each entrance.

- Only a certified agriculturalist or someone under that person's supervision can enter the storage facility.

Disposal of Pesticide Containers or Contaminated Material

- All paper or cardboard pesticide containers, paper packaging material, or other paper material used to clean up spills should be burned or disposed of at a landfill site.

- Make sure that people and animals are kept away from the smoke and that the smoke is not directed toward buildings, highways, roads, or outdoor public areas.

- Plastic material must not be burned.

- Unrinsed containers can contain as much as 3% of the original formulation. If this amount of toxic pesticide is discarded with the container, it could

TABLE 1–5. Ontario Classification of Pesticides

Schedule	Pesticide Category	Persons who may use the pesticide
1	Restricted	Licensed applicator or certified agriculturist under permit approval
5	Agricultural	Licensed applicator under permit approval or certified agriculturist with certificate
2	Pest control industry and agriculture	Licensed applicator or certified agriculturist
3	Consumer, pest control industry and agriculture	Homeowner, licensed applicator, and certified agriculturist
4	Unrestricted	Homeowner, licensed applicator, and certified agriculturist
6	Unrestricted institutional package	Homeowner, licensed applicator, and certified agriculturist

be dangerous to other people handling it or to the environment (e.g., your water supply).

- Rinse all metal, plastic, or glass containers three times with water and add the washings to the spray tank. Alternatively, use a rinsing device. Rinsers can be used to puncture the bottom of a metal or plastic container and rinse the residue directly into the spray tank. This procedure takes less than a minute.

- Return the rinsed containers for recycling to any dealer cooperating in the pesticide container collection and recycling program.

- To dispose of unwanted or contaminated pesticide product:

  — Contact your local supplier. It is sometimes possible to return unused pesticide if it is still in its original container.
  — The Ministry of the Environment has an agreement with Safety-Kleen for the disposal of unwanted pesticides on a user-paid basis. Contact Safety-Kleen in London, Ontario at (519) 451-6630 for disposal of unwanted or contaminated pesticides.
  — Contact a licensed waste hauler (licensed under the *Environmental Protection Act* (EPA) to carry hazardous waste) to arrange for disposal of your unwanted or contaminated pesticide. Please check your local yellow pages under Liquid Waste Removal, or Waste Management to arrange for proper disposal, or consult the local Ontario Ministry of the Environment office for additional information. Watch your local paper or trade publication for obsolete farm pesticides collection and disposal programs, or contact your dealer for further information. On these days, you can turn over surplus or unwanted pesticide concentrates (maximum 25 L) for disposal at no cost.

Types of Application Equipment

Spraying

- Spraying is one of the most widely used and effective methods of applying pesticides.

- The nozzles should be clean and pressure maintained to achieve a fine spray that will result in uniform coverage when the mixture is applied up to the point of runoff.

- Complete coverage is the objective — be sure to spray both the lower and upper leaf surfaces thoroughly.

Fogs

- Fogs are produced by several kinds of machines.

- These machines all use heat from different sources to vapourize the pesticide.

- Fogging can be a very efficient method of pesticide application provided the operator follows the basic instructions.

Granular Application

- Several types of applicators are available for applying granular pesticides.

- Be sure the applicator does not grind or fracture the granules.

Smokes

- Smokes are a very simple but effective means of pesticide application.

- There is no equipment involved — containers are simply placed on the path and lit.

- Do not use smokes in very old, leaky greenhouses or during high winds.

- Do not have combustibles, such as straw, near containers.

Ultra-Low Volume

- There are several types of ultra-low volume (U.L.V.) applicators available.

- They atomize the pesticide solution into an extremely small particle size (7–20 microns).

- Distribution through the greenhouse is by a forced-air fan system.

Electro-Static Sprayers

- Electro-static sprayers (E.S.S.) add an electrical charge to the fine spray particles.

- This enhances plant coverage by the pesticide and reduces drift.

Wetting Agents

In the following discussion, the term "wetting agent" includes spreaders, stickers, and surfactants, although these terms do have slightly different technical meanings.

- Water will not always spread evenly over a surface. Its hydrophilic nature creates a high surface tension so that, when placed on a leaf (hydrophobic) surface, it forms large droplets that easily roll (with the pesticides) off the leaf and onto the ground.

- Reducing the water's surface tension by adding a wetting agent allows the water to make better contact with the leaves. Consequently, the pesticides spread more evenly over the leaf surface.

- Most pesticides are formulated with a wetting agent in them. However, in some cases (due to air or water temperature, water hardness, type of leaf surface, stage of plant growth, and/or the type of formulation), the amount may not be adequate. Consult the label for specific recommendations.

- A simple method of determining if the amount of wetting agent present is sufficient is to spray about 3 m of bed area. Examine both the upper and lower surfaces of leaves at different growth stages for evidence of uniform wetting.

- If wetting is not uniform, add 125 mL of spreader per 1000 L of spray. Spray another 3 m of the bed and re-examine. Continue until wetting is satisfactory.

- Wetting agents help the spray solution to "wet" powdery mildew mycelium and improve control. However, an excessive amount of wetting agent can cause plant damage, excessive foaming (which will cause pumping problems), or runoff (resulting in poor control).

Water for and Pesticide Application

It is very important to neutralize alkaline water when using the water for irrigation and pesticide spray-tank mixtures.

Pesticide Spray-Tank Mixtures

- Because many pesticides decompose in alkaline water, try to use pesticides diluted with alkaline water immediately.

- "Spraying immediately" is not always possible. Note that any delay in applying spray mixtures will result in pesticide loss due to decomposition and, possibly, a corresponding decrease in control. To avoid this possibility, neutralize alkaline water before adding any pesticides. Dissolve ammonium dihydrogen phosphate at the rate of 50 g/100 L water first, then add pesticides or use phosphoric acid to lower the pH to 5.0.

- The rate of decomposition depends on the pesticide, the concentration of pesticide in the tank (dilution factor), and temperature.

- The phosphate is not always necessary, but this practice provides insurance against pesticide loss. Phosphate costs substantially less than pesticides. Also, the added phosphate will be available as a foliar nutrient.

- Water-soluble fertilizers are used occasionally with pesticides as a tank mixture. In this case, it is important to choose acidic fertilizers (which make the addition of ammonium dihydrogen phosphate unnecessary). Do not use alkaline fertilizers for this purpose — the amount of phosphate recommended above will not be sufficient to neutralize the water, and pesticide decomposition may increase.

Agribrom

- Agribrom is registered for use as a water treatment to control algae.

- To be effective, it must be constantly present in the irrigation water at a low level.

- If irrigation water is being recirculated and Agribrom is added every time the water is reused, monitor bromide levels and suspend use if bromide levels are high.

- Treating reservoir water may also elevate bromide levels, so it is advisable to inject Agribrom just as the water is applied to the crop.

- Follow label directions carefully.

Wood Preservatives

- Wolmanized lumber is safe for greenhouse use.

- Copper napthanate has caused some crop injury to poinsettia.

- Other wood preservatives should not be used.

New Pesticide Packaging Method

To simplify disposal of empty pesticide packages, the industry has re-introduced a soluble package that dissolves in the tank of the farm sprayer.

- Water-soluble packaging under the names such as Clean Pak, Solupak, and Toss-N-Go is used for dry flowable and wettable powder pesticide formulations.

- In most cases, the water-soluble packaging material is PVA (poly vinyl alcohol). This material dissolves completely when added to the water in the sprayer tank according to instructions.

Handling

- Do not allow water-soluble pouches to become wet prior to adding them to the sprayer tank.

- Do not handle the pouches with wet hands or wet gloves.

- Do not remove water-soluble pouches from the overwrap (outer package) except when adding them to the sprayer tank.

- Always reseal the outer package to protect the remaining pouches from moisture.

Mixing

- After spray tank is one-quarter full of water and the agitator is running, add the water-soluble pouches to the tank.

- Depending on the water temperature and the degree of agitation, these pouches dissolve completely within 5 minutes.

- As tank continues to fill, add any other compatible pesticides.

Compatibility

- Do not add a pesticide that is incompatible with the PVA packaging material. The PVA material is not soluble with summer-type oils (e.g., Superior Oil).

- Do not combine with the pouches any material containing boron (e.g., Solubor), chelated micronutrients, or water-soluble fertilizers. The combination is likely to cause a sticky, insoluble substance in the tank.

- After applying boron, chelated micronutrients, or water-soluble fertilizers, completely empty and rinse the spray tank before using any product packaged in PVA.

- Read all labels and instructions carefully. For more details, contact your farm chemical dealer.

Pesticide Concentration

- Brands of a pesticide from different companies often contain different concentrations of the same chemical.

- If you use a brand with a concentration different from that listed in this publication, you will need to adjust the rate of application to apply the same amount of actual chemical (active ingredient).

Seed Treatments

- Seed dressings or treatments are poisonous to people and livestock.

- Do not inhale the fumes or dust when treating or handling treated seed.

- Wear neoprene or nitrile gloves.

- Wash all residue of these chemicals from your skin after finishing the treatment. Chemically treated seed is poisonous.

Pesticide Drift

Growers are responsible for any material discharged from their sprayers no matter where it is found. This includes liability for adverse affects such as damage to crops or to ornamental plants, and illegal or unacceptable residue on neighbours' crops or property. You could also be responsible for allergic or asthmatic reactions of bystanders even if they are not on your property.

Take all precautions necessary to prevent drift from the target site that might implicate you in any damaging action.

To avoid exceeding the residue tolerance for insecticides, herbicides and fungicides:

- Do not apply products beyond their preharvest interval as stated on the product label.
- Apply only those products registered for the intended crop and pest.
- Do not apply more than the recommended amount.
- Do not apply products more often than recommended on the label.

Chemical Activity and Toxicity

*The relative toxicity of a pesticide may be referred to as its LD_{50}. This is the amount of the active ingredient (a.i.) of the chemical in milligrams used per kilogram of test animal (usually female rats) that kills 50% of the test animals. This is commonly measured as the acute oral LD_{50} (above) which refers to the chemical ingested through the mouth or nose. Dermal LD_{50} figures, or skin penetration, are also available. The higher the LD_{50} figure, the less toxic the product is to humans.

Many pesticides of low acute toxicity cause long-term effects in laboratory animals. Users are therefore warned that these could be detrimental to their health. Exposure should be reduced to a minimum by wearing protective clothing. Gloves, goggles, and long-sleeved shirts are particularly effective.

Inclusion of a product in these tables does not necessarily imply registration for greenhouse use or registration for a specific crop. **Please read every product label!**

TABLE 1–6. Insecticides and Miticides

Trade Name	Common Name	LD_{50} (mg a.i./kg)*	Chemical Family	Ontario Sch.
Avid	avermectin	300	avermectin	3
Dipel, Thuricide, Vectobac	bacillus thuringiensis	15,000+	biological	3
Diazinon, Basudin	diazinon	300	organophosphate	2
DDVP	dichlorvos	80	organophosphate	3
Thiodan	endosulfan	110	organochlorine	2
Vendex	fenbutatin oxide	2,631	organotin	3
Impower	imidacloprid	1,858	chloronicotinyl	5
Malathion	malathion	1,400	organophosphate	3
Dibrom	naled	430	organophosphate	2
Nicotine, Smoke	nicotine	50	botanical	2
Parathion, Smoke	parathion	3.6	organophosphate	5
Ambush, Pounce	permethrin	4,000+	synthetic pyrethroid	3
Dyno-Mite	pyridaben	1,350	pyridazinone	2

TABLE 1–7. Fungicide Toxicity

Trade Name	Common Name	LD_{50} (mg a.i./kg)*	Chemical Family	Ontario Sch.
Benlate	benomyl	10,000+	benzimidazole	3
Agribrom	bromine	1,390		3
Captan, Maestro	captan	9,000	phthalimide	2
Exotherm Termil	chlorothalonil	10,000+	aromatic hydrocarbon	3
Botran	dichloran	10,000+	dicarboximide	3
Fixed Copper, Tricop, Basicop, Kocide 101	fixed copper		inorganic	
Rovral	iprodione	3,500	dicarboximide	3
No-Damp	oxine benzoate	1,000+	aromatic hydrocarbon	3
Manzate 200	mancozeb	6,750	dithio carbamate	3
Nova	myclobutanil	1,870	triazole	2
Previcur	propamocarb hydrochloride	2,000–2,900	carbamate	2
Mycostop	streptomyces griseoviridis	Not hazardous to animals according to animal studies	microbial fungicide	3
Microfine Sulphur	sulphur	Practically non-toxic to humans and animals		6

TABLE 1–8. Reported Effects of Registered Insecticides/Miticides on Biological Control Agents[a,b,c]

Insecticides	*Encarsia formosa + Aphidius*	*Phytoseiulus persimilis*	*Amblyseius cucumeris + Hypoaspis*	*Aphidoletes aphidimyza*	*Orius spp.*
Ambush	H(56–84)	H(56–84)	H(56–84)	H(56–84)	H(56–84)
Avid	H(21)	H(14)	H(14)	H(21)	H(21)
DDVP	H(7)	H(3-7	H(3-7	H(3)	H(7)
Diazinon or Basudin	H(28–42)	H(7)	H(7–21)	H(42–56)	H(30)
Dibrom (F)	H(7)	H(3-7)	H(3)	H(7)	H(3)
Dipel/Foray	S(0)	S(0)	S(0)	S(0)	S(0)
Dyno-Mite	H(>28)	H(7)	H(28-36)	H(>28)	H(28-35)
Impower (I)	S	S(0)	S(0)	S	H (28-42)
Insecticidal Soap	H(0)	H(0)	H(0)	H(0)	H(0)
Malathion	H(56–84)	H(7–14)	H(56–84)	H(14-70)	H
Nicotine (F)	I(3)	H	H(1-7)	H(1-7)	I
Parathion (F)	H(56–84)	H(3-14)	(42–56)	H(56–84)	H
Thiodan	H(56–84)	H(4–14)	H(42–70)	H(56–84)	H
Vectobac	S	S	S	S	S
Vendex	S	S	S	S	S

[a] Numbers in parentheses refer to residual toxicity to biological agent, in days, where reliable data exists.
S = Safe; H = Harmful; I = Intermediate; "—" means no data is available, so presume toxic unless otherwise proven; F = fumigant; I = through irrigation system.

[b] This table serves only as a guide to possible effects of pesticides. Variations in toxicity may occur under varying conditions

[c] This table was compiled from information produced by Applied Bionomics Ltd., Koppert Biological Systems, and Biobest Biological Systems. Where discrepancies existed in the available information, it provides a range of residual toxicities or the more conservative figure.

TABLE 1–9. Reported Effects of Registered Fungicides on Biological Control Agents[a,b,c]

Fungicides	*Encarsia formosa* and *Aphidius*	*Phytoseiulus persimilis*	*Amblyseius cucumeris* + *Hypoaspis*	Aphidoletes aphidimyza	*Orius* spp.
Benlate	S(0)	H(14-21)	H(14-21)	S(0)	S(0)
Botran	S	S	S	S	—
Exotherm Termil	S(0)	S(0)	I	S(0)	S(0)
Maestro	S(0)	S(0)	S(0)	S(0)	S(0)
Manzate	S(0)	S(0)	S	H	S(0)
Mycostop	S	S	S	S	S
Nova	S	S(0)	—	—	S(0)
Previcur	S(0)	S(0)	S	—	—
Rovral	S(0)	S(0)	S(0)	S(0)	S(0)
Sulphur	H(>28)	S(0)	I	I	S

[a] Numbers in parentheses refer to residual toxicity to biological agent, in days, where reliable data exists.
S = Safe; H = Harmful; I = Intermediate; " —" means no data is available, *so presume toxic unless otherwise proven*

[b] This table serves only as a guide to possible effects of pesticides. *Variations in toxicity may occur under varying conditions*

[c] This table was compiled from information produced by *Applied Bionomics Ltd.*, *Koppert Biological Systems* and *Biobest Biological Systems.* Where discrepancies existed in the available information, it provides a range of residual toxicities *or* the more conservative figure.

Pesticide Certification for Ontario Farmers

- Regulation 914 of the Pesticides Act makes it mandatory for farmers to be certified through the Grower Pesticide Safety Course to buy and use Schedules 1, 2 or 5 pesticides on land they farm.

- There must be at least one Certified Grower for each farm operation.

- Under the *Pesticides Act*, you are a grower (farmer) if you:

  — currently use farm land for agricultural or forestry production and
  — that farmland is classified as farmland property under Section 7 of the *Ontario Assessment Act.*

Training for Assistants Using Schedule 2 or 5 Pesticides

- As of January 2000, all assistants must have formal pesticide safety training, recognized by the Ministry of the Environment, before they can handle or use Schedule 2 or 5 pesticides under the supervision of a Certified Grower.

- This applies to all assistants, including family members, farm employees and seasonal workers.

- Trained Assistants do not have to write an exam.

- Trained Assistants must be 16 years of age or older.

- There are two training options for assistants. Assistants can:

  — attend a Grower Pesticide Safety Course and not write the certification examination, or
  — attend an on-farm training session presented by a qualified Trained Assistant Instructor.
- For more information and a listing of courses and exam-only session dates and locations, check the Ontario Pesticide Education Program Web site at www.ridgetownc.uoguelph.ca/opep/.

- To register for a Grower Pesticide Safety Course or GPSC Exam-Only Session (if you are renewing your certificate) or for information about Trained Assistants anywhere in Ontario please:

  — call 1-800-652-8573 or 519-674-1580, or
  — fax 1-519-674-1589, or
  — e-mail opep@ridgetownc.uoguelph.ca

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2. Factors Affecting Greenhouse Production

The Ontario greenhouse vegetable industry has undergone many changes this past decade. Responding to improved production practices, efficiencies, quality and expanding markets, the industry has more than doubled in just eight years. As of 2000 there were 418 hectares of greenhouses devoted to vegetable production, up from 142 hectares in 1990, with an approximate farm gate value of $260 million. Most of the expansion has been in the Leamington area in southwestern Ontario, with an average size of 2.5 ha/operation (5.5 acres/operation) compared to 1.3 ha/operation (2.8 acres/operation) in the rest of Ontario.

Since 1997 double polyethylene-covered greenhouses have replaced glass as the choice material of construction. They are less expensive to build, saving 10%–20% in heating costs and have similar production/unit area as glass. The use of gutter vented, double polyethylene greenhouses has increased as this reduces electrical costs for fan cooling in the summer.

Other changes that have helped the industry expand include:

- an increase in gutter height to improve the greenhouse environment
- installation of environment control computers in all new construction and retrofitting of older operations
- the dramatic increase of hydroponic/soilless culture, where most operators grow in rockwool, foam, NFT or peat and only 5%–7% grow in soil.

Integrated Pest Management (IPM) is practised by Ontario greenhouse vegetable operators. Manipulation of the greenhouse environment, scouting programs and biological control agents are instrumental in maintaining a high quality product.

At present, 57% of the acreage is planted to tomatoes, 31% to cucumbers, 11% to peppers and 1% to lettuce and other crops such as oriental vegetables. Tomato acreage has expanded since growers switched from the pink coloured tomato cultivars to the more popular red coloured tomato cultivars.

Marketing is the key to a flourishing industry. High quality, flavour and service are important factors for a successful market strategy, and the Ontario Greenhouse Vegetable Growers (OGVG), formerly the Ontario Greenhouse Vegetable Producers' Marketing Board, plays a key role. Established in 1967, the OGVG has been instrumental in marketing and promoting greenhouse grown tomatoes and cucumbers.

Introduction

Maximizing production and quality in a greenhouse operation requires proper management and control of plant growth. Factors such as light, temperature, water, nutrition, insect and disease pressures, the crop and cultivars grown are key components affecting growth and yield. Some of these factors are easily controlled, while for others there is either no control or no economical way to control them.

For example, prevailing low light conditions in winter are not normally adjusted, except where artificial light is used to supplement day length at seedling or plant raising stages. However, during the summer when light levels are high, shade curtains or whitewashing the greenhouse exterior are used to reduce light transmission to the crop.

Control can be imposed on the plant by manipulating one or all of the aforementioned factors.

2. Factors Affecting Greenhouse Production

The Ontario greenhouse vegetable industry has undergone many changes this past decade. Responding to improved production practices, efficiencies, quality and expanding markets, the industry has more than doubled in just eight years. As of 2000 there were 418 hectares of greenhouses devoted to vegetable production, up from 142 hectares in 1990, with an approximate farm gate value of $260 million. Most of the expansion has been in the Leamington area in southwestern Ontario, with an average size of 2.5 ha/operation (5.5 acres/operation) compared to 1.3 ha/operation (2.8 acres/operation) in the rest of Ontario.

Since 1997 double polyethylene-covered greenhouses have replaced glass as the choice material of construction. They are less expensive to build, saving 10%–20% in heating costs and have similar production/unit area as glass. The use of gutter vented, double polyethylene greenhouses has increased as this reduces electrical costs for fan cooling in the summer.

Other changes that have helped the industry expand include:

- an increase in gutter height to improve the greenhouse environment
- installation of environment control computers in all new construction and retrofitting of older operations
- the dramatic increase of hydroponic/soilless culture, where most operators grow in rockwool, foam, NFT or peat and only 5%–7% grow in soil.

Integrated Pest Management (IPM) is practised by Ontario greenhouse vegetable operators. Manipulation of the greenhouse environment, scouting programs and biological control agents are instrumental in maintaining a high quality product.

At present, 57% of the acreage is planted to tomatoes, 31% to cucumbers, 11% to peppers and 1% to lettuce and other crops such as oriental vegetables. Tomato acreage has expanded since growers switched from the pink coloured tomato cultivars to the more popular red coloured tomato cultivars.

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14

The major objective of a greenhouse is to provide an environment for optimum plant growth. Light, carbon dioxide, water, nutrients and temperature are all required for plant growth. Light is often considered to be the limiting factor and, therefore, greenhouses are built to maximize light penetration so that growth can also be maintained during the darker months. Section 2 discusses some of the growth factors related to greenhouse production.

Vegetative or Generative Plants

Adjustments to light, temperature, water and nutrient regimes ensure that a certain form or look of plant is obtained. For example, a vegetative plant is one that produces more leaves than flowers and fruit. In this case, the plant has large, thick, dark green leaves, a thick stem with a light green tinge at the growing end; large, rough flowers on weak flower stems and trusses; and fruit development and size is small compared to the size of the plant. Root growth may be extensive.

A generative plant, on the other hand, has smaller leaves, a thin stem with a purple tinge at the growing point; smaller, numerous flowers prominently displayed; and large fruit compared to the size of the plant, and possibly poor fruit quality because of over exposure to the sun. A balance between these two types of plants is optimal.

At certain times of the year, the plant must be guided towards the vegetative phase and then shifted towards the generative phase by the grower. Early in the planting cycle the plants tend to be vegetative and control must be implemented early to obtain a generative plant that will provide fruit at the desired time. However, the plants may become too generative and adjustments to the cropping strategies are required to encourage a more vegetative growth.

A plant grown in the early winter months (when light levels are traditionally low) at a low temperature and high humidity will tend to be vegetative (i.e., thick stemmed, large leaves, short stocky plant, with large flowers and small fruit) if amply supplied with water and nutrition. By raising the temperature (within reason), decreasing the humidity, water and nutrition a more controlled plant may be obtained.

Further changes may be made to the way the plant grows by adjusting the day-night temperatures. During sunshine hours, a higher temperature is maintained allowing the plants to manufacture sugars and to grow rapidly. At night, the temperature is lowered so that the sugars manufactured during the day can be translocated or stored in the stem and root growing points, the fruit and the leaves, resulting in thicker, heavier plants. Adjusting the temperature and determining when to make these adjustments are tools continuously used in the greenhouse to obtain a well-balanced, highly productive crop.

Effect of Temperature

Plant temperature has an influence on several important processes, all of which have an effect on growth.

Effect on Photosynthesis and Respiration

Photosynthesis is the process whereby plants convert carbon dioxide (CO_2) and water (H_2O) into carbohydrates and oxygen. This process requires light energy, which means photosynthesis can only take place when visible light is available to the plant. In a way, the plant is storing energy in the form of carbohydrates.

Respiration is the process that accomplishes the opposite effect of photosynthesis, namely the carbohydrates are converted back to carbon dioxide and water, releasing energy. This energy is then used to help processes such as root, leaf and bud initiation and development. Respiration does not depend on light and, therefore, takes place 24 hours a day. The rate of respiration is influenced by temperature.

The net effect of the two processes can be expressed as an accumulation of dry matter, or growth. The optimum temperature to obtain the maximum increase in dry matter depends on the light intensity. The higher the light intensity, the higher the optimum temperature. For most greenhouse crops, this optimum is between 12°C–16°C during low light conditions, and 15°C–25°C when light intensity is high.

Rate of Development of Leaves, Flowers and Roots

These processes require energy and coincide with the rate of respiration. The 24-hour average temperature is important for these activities. For each degree Celsius increase between 10°C –30°C, there is a 10% increase in leaf and flower initiation. Thus, the 24-hr average temperature determines the rate of crop development. Under low light conditions, the 24-hr average temperature is lowered and under high light conditions, the average temperature is raised.

The degree of adjustment is determined by observing the morphological characteristics of the plant. At a low 24-hr average temperature, the plant tends to have shorter internodes, thicker stems and leaves, and large flowers. At a high 24-hr average temperature, the plant tends to have longer internodes, thinner stems and leaves, and small, spindly flowers. Too high or too low a 24-hr average temperature is detrimental to the crop. Higher temperatures weaken the plant and flowers, causing yield reduction, while low temperatures delay harvest or damage flowers resulting in malformed fruits.

Shape and Development

Temperature has an influence on the size and shape of leaves. For example, cucumbers and lettuce have short, wide leaves when the temperature at initiation is low, while at high temperatures the leaves are long and narrow.

The day-night temperature differential influences the shape of the plant. A small or even day-night temperature differential results in more vegetative plants with short internodes, thicker larger leaves, while a large day-night temperature differential results in more generative plants with longer internodes, thinner, smaller leaves. Usually a more even day-night temperature regime is used in early development (to establish a plant) and a differential is used after the flowering and fruit setting stages.

Effect on Humidity

Temperature has a direct influence on humidity. When the temperature increases, the relative humidity (RH) decreases. The reverse is also true. Relative humidity has a direct influence on the transpiration rate and, therefore, on the water status of the plant. In general, plants grown at high RH have larger leaves and longer stems than those grown at a lower RH.

The optimum temperature for each crop influences the above factors and depends on light conditions, the stage of growth, and season. The temperature at which a crop is grown can be used to control the rate of crop growth, its vigour, the shape or morphology of the plants, fruit size, and, ultimately, the yield. Generally, the optimum temperature for lettuce is 17°C –18°C; tomatoes 19°C; peppers 19°C and cucumbers, 21°C. Several temperature schemes have proven beneficial.

Figure 2-1, *Temperature Profile of Greenhouse Crops — Sunny Day* and Figure 2-2, *Temperature Profile of Greenhouse Crops — Cloudy Day* are examples of temperature manipulations used to develop the ideal plant with good form, and a high quality production. This scheme is attempting to maintain a 24 hr average temperature, but allowing for a higher afternoon temperature to increase speed followed by a lower early

FIGURE 2-1. Temperature Profile for Greenhouse Crops — Sunny Days

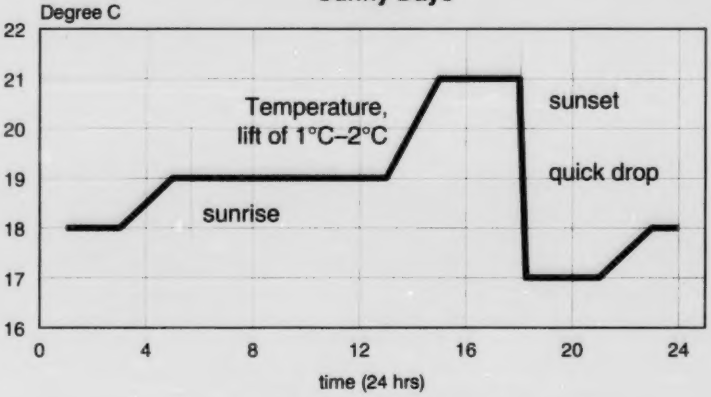
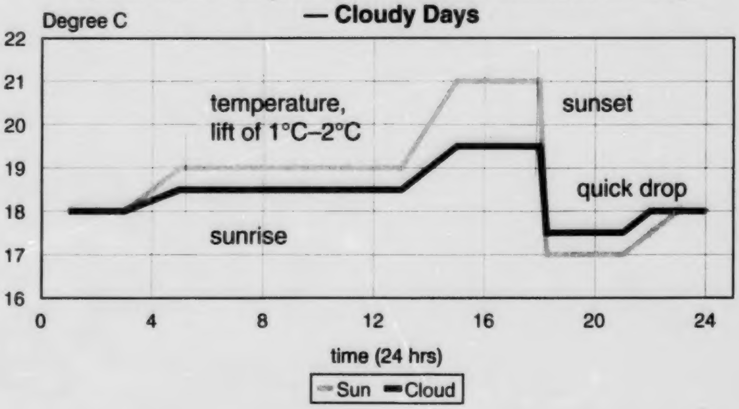


FIGURE 2-2. Temperature Profile for Greenhouse Crops — Cloudy Days



night temperature to create a strong head, root and fruit base.

Temperature Control

Heating

Temperature requirements of the major greenhouse vegetable crops (i.e., tomatoes, cucumbers, peppers, lettuce) vary significantly. The heating requirement for a greenhouse range can be calculated on an hourly, as well as a yearly, basis. Inside and outside temperatures, the type of glazing material, and the surface area of the greenhouse must be known for these calculations. Greenhouse heating companies will design systems suitable for local conditions.

The standard recommendation for a 35°C temperature differential is 350 watts per metre squared (W/m^2) for a glass greenhouse, and 270 W/m^2 for a double polyethylene greenhouse. In southwestern Ontario, a general rule of thumb is 100 hp boiler for 0.4 ha [1 acre] of greenhouse. If thermal curtains are installed, these figures can be reduced by 25%–35%. Although some crops require less heat (e.g., lettuce) than others, the heat requirements for a high temperature crop are usually used in the design of the heating system so that growers can switch more easily to other crops at a later date, if desired.

The most common heating system in Ontario greenhouses is a central heating system. The source of energy is primarily natural gas, with some growers using waste wood. Bunker oil and #2 oil are used as a standby, although a few growers are using it as their main source of energy. Several growers use propane, especially those who are not close to the natural gas supply lines.

Heat is provided in the form of steam or hot water from a centrally-located boiler through a system of heating pipes. The main advantage of such a system is that the pipes can be located in areas where the greatest heat losses occur (i.e., perimeter), or where it is most efficient (i.e., within the crop — about 30–60 cm above the ground). Hot water systems have the added benefit of being able to regulate the temperature of the water within the pipes. Typically, heating pipes are located within the crop to assist in maintaining good air movement around the plants. Crop zone heating pipes used as pipe rail systems for battery/electric powered carts is an additional advantage. This makes the work less strenuous for the employees.

Gas fired unit heaters are an alternative to a central heating system. Although these units can be installed very economically, the major drawbacks are poor temperature distribution, greater temperature fluctuations, lower seasonal combustion efficiency, and the possibility that gases from the flue may enter the greenhouse. Some growers have attached duct work to the units and direct the warm air via large poly tubes distributed between the plant rows to heat the greenhouse. This greatly improves heat distribution within the greenhouse. As well, they provided a direct source of outside air to the fire box in order to minimize the possibility of improper burn.

Cooling

Although greenhouses require a great deal of heat to maintain temperatures during the winter, it is also necessary to reduce temperatures during the warmer months. Cooling is normally accomplished by exchanging greenhouse air with outside air. Data show that one air exchange per minute is required for high temperature, summer conditions. Two systems presently used are natural ventilation (peak ventilation for glass and acrylic houses, gutter ventilation for double polyethylene greenhouses) and forced air ventilation (fan cooled greenhouses). The forced air ventilation system also allows for the installation of a fan and pad system for additional summer cooling. High pressure fogging systems are being used by some growers for both spring and summer cooling, and for humidity control in the winter and spring.

Temperature Sensing and Control

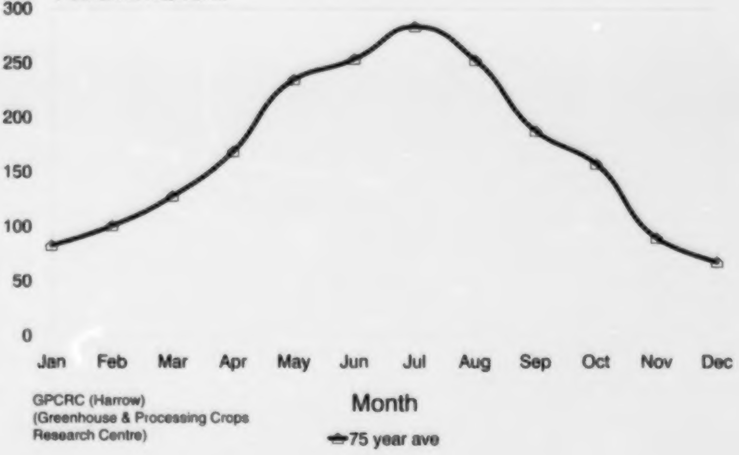
Using computers to maintain the greenhouse temperature and environment is now standard. With a computer the temperature can be automatically controlled depending on the time of day, intensity of sunlight, relative humidity, or many other factors. In addition to a static temperature set point, the computer allows for the ramping of temperatures from night to day. Ramping (controlled temperature increase or decrease) provides more accurate optimum temperatures for plant growth. This allows for a temperature profile that is specific for a selected cultivar or style of growing.

Computers require an extensive initial investment and may be economically viable only for large greenhouse operations. However, the improved temperature, RH control and disease management make computers essential for all greenhouse sizes.

Traditionally, growers use mechanical temperature sensors.. However, electronic sensors (thermistors) are now being used in conjunction with analogue or digital controllers. The sensor measures the temperature in the immediate area and must be placed near the growing point of the plant canopy. As the plant grows, the sensor is raised to monitor the temperature at the growing point.

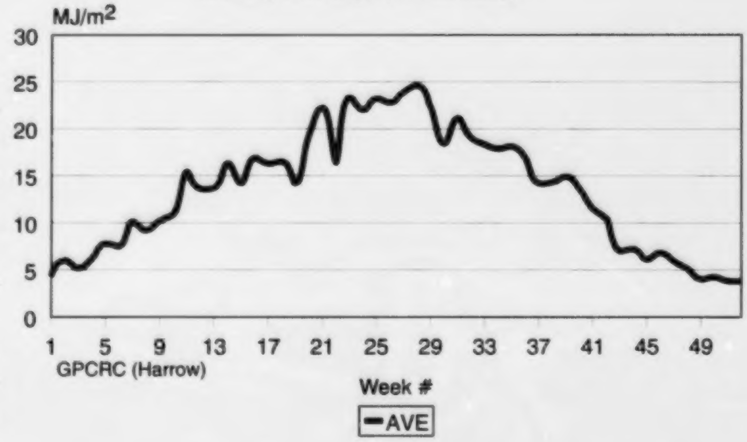
Since temperatures often vary in different parts of the house, the sensor is placed in an aspirated box. The aspirator will draw greenhouse air across the thermometer and give it a more representative sample of temperature.

FIGURE 2-3. Sunshine Hours — 75 year average



GPCRC (Harrow)
(Greenhouse & Processing Crops Research Centre)

FIGURE 2-4. Sunshine Radiation Weekly Average (MJ/m²/day)



GPCRC (Harrow)

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Light

Light is the primary productive factor in plant growth. The process of photosynthesis, by which a green plant takes carbon dioxide from the air, and water from the root zone and manufactures food, is powered by the energy absorbed from light.

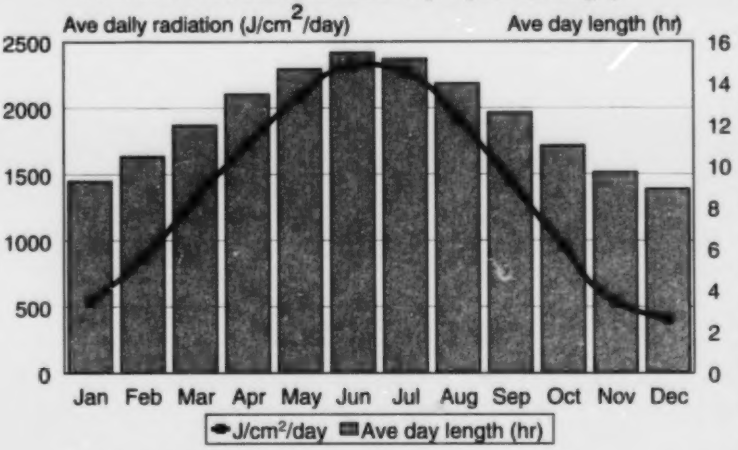
$$6CO_2 + 6H_2O \xrightarrow{Light} C_6(H_2O)_6(sugars) + 6O_2$$

In greenhouse production, light is the fundamental factor in plant growth over which growers have the least control.

Artificial light will support photosynthesis, but energy costs make it uneconomical to grow most vegetable crops this way. However, the use of supplemental light is common in the growing of seedlings and transplants before planting out. In general, supplemental light at 20 watts/m^2 for the desired photoperiod is adequate and economical. It will provide stronger, stockier plants in a shorter period of time during the low light, short days of December and January.

Normal sunlight patterns are presented in Figure 2-3, *Sunshine Hours*, Figure 2-4, *Sunshine Radiation* and Figure 2-5, *Global Radiation*. As there is little light energy available for growth in the mid-winter months relative to the summer months, it often takes twice as long to get the same amount of growth in January as in May. This factor must be considered when scheduling the production of greenhouse vegetable crops. Greenhouse management practices should be adjusted to suit the prevailing light conditions. Therefore, both seasonal and daily temperature and nutrient adjustments must be made in relation to the expected light levels.

FIGURE 2-5. Global Radiation (10-year average)



(Vineland Research Station)

Plants have the ability to adjust to lower light levels. Anatomically, the light capturing chloroplasts are arranged parallel to the sun radiation in leaves produced under high light compared to leaves formed under low light conditions, where the chloroplasts are aligned perpendicular to the sun radiation to capture more light energy. However, the degree of adjustment depends on the age of the plant or leaves, and the length of time of acclimatization. This explains, in part, why spring grown plants are bigger than fall grown plants, even though the same amount of light may be received by the plants.

Interaction Between Light Intensity and Plant Leaf

There is an interaction between leaf size and light intensity. This is particularly true for young, expanding leaves during periods of low light intensity. Research shows that a reduced light intensity is compensated to some degree by a larger leaf surface area without affecting the photosynthetic rate per unit surface area of these leaves. Larger leaves also mean that more light will be intercepted, and so improve the overall conversion efficiency of the plant. These large leaves are usually thin cuticled, and are more prone to damage when manipulated during normal cultural practices. Leaves grown under high light intensity usually have a thicker cuticle.

Light Transmission

The amount of light that is received inside the greenhouse is strongly influenced by the glazing material. Glass has been the traditional glazing for vegetable greenhouses. However, over the past 10 years, double poly greenhouse structures have become increasingly more popular for greenhouse vegetable production. The reasons for this change are energy conservation and low capital construction costs, without loss of productivity. [See Figure 2-6, *Comparison of Light Transmission between Glass and Double Polyethylene Covered Greenhouses*]

Current roof designs and increased gutter height of greenhouses provide for improved light transmission, a better environment and improved growing conditions.

Many conflicting reports have been published on light transmission of different materials. Different measuring techniques usually account for these discrepancies. Light transmission is defined as the ratio of light passed through a material and the original amount of light striking the outer surface of any object when that light is directed perpendicular to the material. In general, only 60%–75% of light striking the outer surface actually reaches the plant.

FIGURE 2-6. Comparison of Light Transmission Between Glass and Double Polyethylene

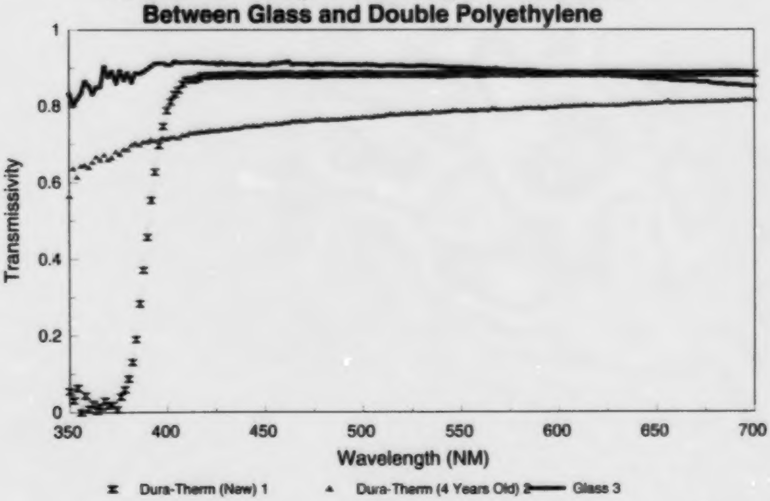


TABLE 2–1. Conversion Table for Light

Light Source	W/sqM to umol/sqm/sec	umol/sqm/sec to W/m^2	lux to umol/sqM/sec	umol/saM/sec to lux	lux to W/sqM
sunlight	4.57	0.22	0.02	54.00	0.00
high pressure sodium (SON/T)	4.98	0.20	0.01	82.00	0.00
ncandescent	5.00	0.20	0.02	50.00	0.00
high pressure mercury	4.52	0.22	0.01	84.00	0.00
metal halide	4.59	0.22	0.01	71.00	0.00

The most useful light for photosynthesis is between 400 and 700 nM wavelength.

Light intensity is often expressed in radiation terms as Watts per metre squared (W/m^2) or Joules per metre squared (J/m^2) or photometrically in lux or foot candles. Table 2-1, *Conversion Table for Light*, shows the conversion factors used to change the light reading expressions. This allows one to compare light readings recorded by different equipment as well as those by the various environment control computers.

Two major factors that determine the light transmission of glazing are the refractive index and the amount of light absorbed by the material itself. Theoretical calculations show that for glass, about 4% of the light is reflected at each glazing/air interface. This means that the maximum light transmission for a single layer of material is about 92%. This explains why light transmission through a double layer of glazing material is considerably less than through a single layer of the same material with a total thickness equal to the double layer.

The maximum theoretical transmission through a double layer material, such as glass, would be 85% indicating that the major loss of light is through reflection, not absorption. This also accounts for the relatively small difference in light transmission between 100 and 150 micron polyethylene films.

Development in the polyethylene film industry has resulted in changes in the light transmission properties of the newer plastics, improving light reception and quality at the plant level. Adjustment of UV transmission to decrease disease incidences and allow bumble bees to function well have been made to the poly films presently used.

Relative Humidity (RH)

Relative humidity is the ratio of the actual amount of water vapour present in a given amount of air (i.e., absolute humidity), to the maximum amount of water vapour that can be held within that volume of air at a given temperature. RH is given as a percentage, and varies between 40% and 100% in most greenhouses.

The actual amount of water in a given volume of air for various relative humidities is given in Table 2-2, *Water Content of Air at 18°C for Various Humidities*. The amount of water vapour which air can contain is strongly correlated with temperature, as illustrated in Table 2-3, *Effect of Temperature on the Saturated Water Content of Air*, almost doubling for every 10°C increase in temperature.

TABLE 2–2. Water Content of Air at 18°C for Various Humidities

Relative Humidity (%)	Water Content (g/m^3)
100	15.7
80	12.6
60	9.4
30	4.7

TABLE 2–3. Effect of Temperature on the Saturated Water Content of Air

Temperature °C	Water Content (g/m^3)
–20	1.1
–10	2.4
0	4.9
10	9.5
20	17.8
30	31.8

Relative humidity is a commonly used term to describe the moisture in the air. However, as shown in Tables 2-2 and 2-3, the water content of the air varies at different temperatures [See Table 2–4, *Vapour Pressure Relations* for an illustration of this.]

TABLE 2–4. Vapour Pressure Relations

Temp.	RH	Max. water	Actual water	Vapor Deficit (g/m^3)
20	70	17.6	12.2	5.4
25	70	23.6	16.4	7.2
30	70	31.7	21.9	10.2

Although the RH is 70% at the 3 temperatures indicated, the actual water present is quite different. The difference between maximum water and actual water present provides a vapour deficit that gives a better knowledge about the drying capacity of the air. For example, at 20°C and 70% RH, the air can hold only 6.4 g/m^3 of water. But at 30°C and 70% RH, it can hold 10.2 g/m^3 water. This difference affects transpiration.

In this example, the lower vapour deficit at 20°C means that the transpirational pull is not as high as at the higher vapour deficit of 30°C. Within the leaf, the air is saturated or is at 100% RH. Air outside the leaf is not fully saturated or in other words is below 100% RH. The difference between these values — that is water vapour in the leaf and the water vapour outside the leaf — determines the transpirational rate.

Water movement from the leaf into the atmosphere occurs through stomata (which are controlled by biological factors such as light, temperature, stature of the plant). Water movement from the leaf into the atmosphere occurs when the stomata are open.

Vapour deficit or vapour pressure deficit (VPD) is the mathematical term, determined by measuring the wet bulb and dry bulb temperatures that are used to determine the optimal conditions for transpiration. Vapour pressure deficit is a commonly used term. Water vapour in the air exerts pressure and is indicated in millibars (mbar) or kiloPascals (kPa) of pressure. Humidity deficit is also used to indicate the difference between the water vapour present in the plant and that present outside. Table 2-5, *VPD Relationship to Temperature and RH*, shows the VPD values from various temperature and RH values. Optimal VPD is 0.4–0.8 kPa (4–8 mbar), and is indicated by the clear values on the chart. Optimal transpiration rate and nutrient uptake coupled with adequate sugars at these VPD values result in healthy vigorous high yielding plants.

Plant vigour and growth rate can be altered by adjusting the VPD. Maintaining too low a VPD results in low transpiration, thicker, larger leaves, thick stems, weaker root systems, and plants more prone to disease infestations. Too high a VPD results in a high transpiration rate, thinner smaller leaves, thinner stems, and a stronger root system. Extreme VPD values or rapid fluctuations in VPD (low or high) are detrimental to plant growth, fruit quality and productivity.

VPD can be adjusted in the greenhouse by altering the heating temperatures, the venting rate, and air movement. Other factors such as the water availability to the crop, or misting or fogging systems also alter the VPD.

If the greenhouse air is heated or cooled without changing the actual amount of moisture present, the relative humidity will decrease or increase respectively. For most greenhouse conditions, a rule of thumb is that for each degree Celsius increase in temperature, the relative humidity drops about 4%–6%. The inverse also holds true. Where different day and night temperature regimes are established, these relative humidity changes occur regularly. For instance, many growers increase the temperature at sunrise by about 3°C and, thus, lower the relative humidity by 12%–18%, inducing an increased transpiration rate. In the evening, the drop in temperature increases the relative humidity, requiring some ventilation to prevent disease development.

When moist air reaches the saturation point, condensation occurs on the cooler surfaces in the greenhouse. During the day, leaves are usually warmer than the surrounding air, but due to radiant heat loss at night, the leaf temperature may drop 1°C or 2°C below ambient air temperature. If the RH in the greenhouse is near 95%, condensation may take place on leaf surfaces. Prolonged periods of high relative humidity and free water encourages bacterial diseases and the germination of many fungal spores, such as *Botrytis* or powdery mildew.

M121

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TABLE 2–5. VPD Relationship to Temperature and RH (mbars)

TEMP °C	RH 50	55	60	65	70	75	80	85	90	95
15.0	8.5	7.7	6.8	6.0	5.1	4.3	3.4	2.6	1.7	0.9
16.0	9.1	8.2	7.3	6.4	5.5	4.6	3.6	2.7	1.8	0.9
17.0	9.7	8.7	7.8	6.8	5.8	7.5	3.9	2.9	1.9	1.0
18.0	10.3	9.3	8.3	7.2	6.2	5.2	4.1	3.1	2.1	1.0
19.0	11.0	9.9	8.8	7.7	6.6	5.5	4.4	3.3	2.2	1.1
20.0	11.7	10.5	9.4	8.2	7.0	5.9	4.7	3.5	2.3	1.2
21.0	12.4	11.9	9.9	8.7	7.5	6.2	5.0	3.7	2.5	1.2
22.0	13.2	11.9	10.6	9.3	7.9	6.6	5.3	4.0	2.6	1.3
23.0	14.1	12.6	11.2	9.8	8.4	7.0	5.6	4.2	2.8	1.4
24.0	14.9	13.4	11.9	10.4	9.0	7.5	6.0	4.5	3.0	1.5
25.0	15.8	14.3	12.7	11.1	9.5	7.9	6.3	4.8	3.2	1.6
26.0	16.8	15.1	13.4	11.8	10.1	8.4	6.7	5.0	3.4	1.7
27.0				12.5	10.7	8.9	7.1	5.4	3.6	1.8
28.0				13.2	11.3	9.5	7.6	5.7	3.8	1.9
29.0					12.0	10.0	8.0	6.0	4.0	2.0
30.0					12.7	10.6	8.5	6.4	4.2	2.1

Note: The clear area is the optimum range for most greenhouse crops
1 mbar = 0.1 kPa
0.1 kPa = 0.7 g/m^3 = 3% RH

Relative humidity also affects pollen transfer. For tomatoes, it is important that the RH is between 70%–75% for pollination. This permits the proper release of the pollen from the anthers on to the stigma. After pollination, a higher RH helps the pollen to germinate, improving both fertilization and increasing fruit size.

An extremely low RH may occur when large amounts of dry air enter the greenhouse on a bright, sunny day during the early part of the year. The cooling cycle must be monitored closely during this period. Too much ventilation reduces the RH too rapidly and may cause burning of tender foliage or curling of young cucumber fruit, decreasing fruit quality and yield.

Misting or fogging systems that maintain the RH can be installed to prevent damage to specific crops. During the summer, when forced ventilation is needed, a high relative humidity is often not a problem during the day, unless a fan and pad system has been installed for cooling. However, at night, ventilation and/or heating are often required to prevent excessively high RH and condensation on the foliage.

Carbon Dioxide (CO_2)

The ambient CO_2 level of outside air is about 340 ppm (ppm = parts per million) on a volume basis. During the process of photosynthesis, plants absorb carbon dioxide from the air and combine it with water (H_2O) to produce carbohydrates necessary for plant growth. This process is energy driven which can only take place when there is sufficient solar radiation (light). Consequently, the CO_2 level in an air-tight greenhouse (if not adequately vented) can drop well below the ambient level, especially during sunny periods. Low CO_2 levels reduce photosynthetic activity, lowering plant growth and fruit yield. Significant reductions in the CO_2 concentration in the greenhouse have been observed during periods of bright sunlight, even with summertime ventilation (as low as 200 ppm). Supplemental CO_2 during ventilation may be economical, but it must be considered on its own merit for each operation.

Research has shown that plant growth is improved by 15%–20% in greenhouses when CO_2 levels are increased to 800–1,300 ppm during the daytime. The optimum level of supplementation depends on the crop and the air movement within the greenhouse. In general, the optimum CO_2 level with good air

TABLE 2–5. VPD Relationship to Temperature and RH (mbars)

	RH									
TEMP °C	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**
15.0	8.5	7.7	6.8	6.0	5.1	4.3	3.4	2.6	1.7	0.9
16.0	9.1	8.2	7.3	6.4	5.5	4.6	3.6	2.7	1.8	0.9
17.0	9.7	8.7	7.8	6.8	5.8	7.5	3.9	2.9	1.9	1.0
18.0	10.3	9.3	8.3	7.2	6.2	5.2	4.1	3.1	2.1	1.0
19.0	11.0	9.9	8.8	7.7	6.6	5.5	4.4	3.3	2.2	1.1
20.0	11.7	10.5	9.4	8.2	7.0	5.9	4.7	3.5	2.3	1.2
21.0	12.4	11.9	9.9	8.7	7.5	6.2	5.0	3.7	2.5	1.2
22.0	13.2	11.9	10.6	9.3	7.9	6.6	5.3	4.0	2.6	1.3
23.0	14.1	12.6	11.2	9.8	8.4	7.0	5.6	4.2	2.8	1.4
24.0	14.9	13.4	11.9	10.4	9.0	7.5	6.0	4.5	3.0	1.5
25.0	15.8	14.3	12.7	11.1	9.5	7.9	6.3	4.8	3.2	1.6
26.0	16.8	15.1	13.4	11.8	10.1	8.4	6.7	5.0	3.4	1.7
27.0				12.5	10.7	8.9	7.1	5.4	3.6	1.8
28.0				13.2	11.3	9.5	7.6	5.7	3.8	1.9
29.0					12.0	10.0	8.0	6.0	4.0	2.0
30.0					12.7	10.6	8.5	6.4	4.2	2.1

Note: The clear area is the optimum range for most greenhouse crops
1 mbar = 0.1 kPa
0.1 kPa = 0.7 g/m^3 = 3% RH

Relative humidity also affects pollen transfer. For tomatoes, it is important that the RH is between 70%–75% for pollination. This permits the proper release of the pollen from the anthers on to the stigma. After pollination, a higher RH helps the pollen to germinate, improving both fertilization and increasing fruit size.

An extremely low RH may occur when large amounts of dry air enter the greenhouse on a bright, sunny day during the early part of the year. The cooling cycle must be monitored closely during this period. Too much ventilation reduces the RH too rapidly and may cause burning of tender foliage or curling of young cucumber fruit, decreasing fruit quality and yield.

Misting or fogging systems that maintain the RH can be installed to prevent damage to specific crops. During the summer, when forced ventilation is needed, a high relative humidity is often not a problem during the day, unless a fan and pad system has been installed for cooling. However, at night, ventilation and/or heating are often required to prevent excessively high RH and condensation on the foliage.

Carbon Dioxide (CO_2)

The ambient CO_2 level of outside air is about 340 ppm (ppm = parts per million) on a volume basis. During the process of photosynthesis, plants absorb carbon dioxide from the air and combine it with water (H_2O) to produce carbohydrates necessary for plant growth. This process is energy driven which can only take place when there is sufficient solar radiation (light). Consequently, the CO_2 level in an air-tight greenhouse (if not adequately vented) can drop well below the ambient level, especially during sunny periods. Low CO_2 levels reduce photosynthetic activity, lowering plant growth and fruit yield. Significant reductions in the CO_2 concentration in the greenhouse have been observed during periods of bright sunlight, even with summertime ventilation (as low as 200 ppm). Supplemental CO_2 during ventilation may be economical, but it must be considered on its own merit for each operation.

Research has shown that plant growth is improved by 15%–20% in greenhouses when CO_2 levels are increased to 800–1,300 ppm during the daytime. The optimum level of supplementation depends on the crop and the air movement within the greenhouse. In general, the optimum CO_2 level with good air circulation is around 1,000 ppm on sunny days and 400 ppm on cloudy days, or when vents are opened more than 10%. In Ontario, most greenhouse growers with year-round operations introduce supplemental CO_2 into their greenhouses, monitored with carbon dioxide controllers to maintain set points.

Methods to Increase CO_2

The most common method of increasing CO_2 levels has been through fuel combustion such as natural gas, propane or low sulphur kerosene. These fuels are burned in special units positioned at appropriate locations in the greenhouse to improve distribution. Flue gas CO_2 from the heating plant/boiler system, is an alternative source for supplementing CO_2. Heat available from flue gas CO_2 generation is stored as hot water in large buffer tanks for use at night when heat is required. Liquid CO_2 has become popular and with increased use, more economical.

There is an increased interest in supplementing CO_2 during the summer months when vents are fully opened. Maintaining 400 ppm CO_2 levels when vents are fully opened improves fruit size, quality and colour. Liquid CO_2 and flue gas CO_2 lend themselves well for summer CO_2 supplementation. This potential increase in yield must be balanced with the increased cost — and the possibility of poor returns due to market conditions.

The rate of supplemental carbon dioxide is dependent on the infiltration rate of outside air into the greenhouse. Burner capacity or the rate of supplemental liquid carbon dioxide for different types of greenhouses is listed in the OMAFRA Factsheet, *Carbon Dioxide in Greenhouses*, Order No. 00-077. As a rule, a CO_2 supplementation rate of 45–65 kg/ha/hr maintains 1,000 ppm in a closed greenhouse, or 350–400 ppm in a vented greenhouse. This Factsheet also deals with CO_2 distribution, cost and dangers of incomplete combustion, and should be consulted when considering CO_2 supplementation.

Energy Conservation

The judicious use of energy conservation technology is recommended for commercial greenhouses. However, consideration must be given to the impact of this technology on crop production.

Energy conservation techniques, such as double poly greenhouses and/or double walled, SDP/acrylic side walls are commonly used in Ontario. Changes to management and cultural practices have been implemented to compensate for the lower light transmission and the lower rate of air exchange per hour without any detrimental effect on crop production. (Natural air exchange in glass house is 0.75–1.5 exchanges/hr, while double poly greenhouses have 0.2–1.0 exchanges/hr) The great increase in energy costs in the 1970's resulted in the implementation of energy conservation techniques, as well as lower greenhouse temperature settings. But most Ontario greenhouse growers have concluded that maintaining a lower 24 hr average temperature to conserve energy is not cost effective, due to lower yield.

Shade/energy curtains are not commonly used in Ontario vegetable greenhouse production, although there is now greater interest shown as some newer greenhouses are using them.

Water

Water supply and quality for greenhouse crop production is very important. Select a site with ample supply of high quality water. Most greenhouse vegetable operations in southwestern Ontario use municipal water from the Great Lakes. Other operations rely on well water or rainfall collected in ponds. Rivers or streams are not recommended as the only source of water as the possibility of contaminants causing damage to the greenhouse crop is higher.

In most areas, municipal water is of adequate quality, with soluble salts of less than 0.750 milliSiemens per centimetre (mS/cm)[1]. Since well water may be of very poor quality, and unsuitable for continuous irrigation, water tests must be conducted.

Generally, water quality for greenhouse use may be divided into 3 classes. [See Table 2–6, *Classification of Water Quality*] Class 1 water is satisfactory for all purposes. Class 2 water may be used in substrate and soil culture where leaching can be done. However, it is unsuitable for NFT (nutrient film technique) crops or

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[1] 1 mS/cm ~1 m mhos/cm or 1000 µS/cm ~ 1000 µmhos/cm

TABLE 2–6. Classification of Water Quality

Class	Electrical Conductivity (mS/cm)	Sodium (ppm)	Chloride (ppm)	Sulphate (ppm)
1	0.5	30	50	100
2	0.5–1	30–60	50–100	100–200
3	1.0–1.5	60–90	100–150	200–300

where recirculation of nutrient solutions is planned. Class 3 water is the least desirable, and should not be used for salt-sensitive crops.

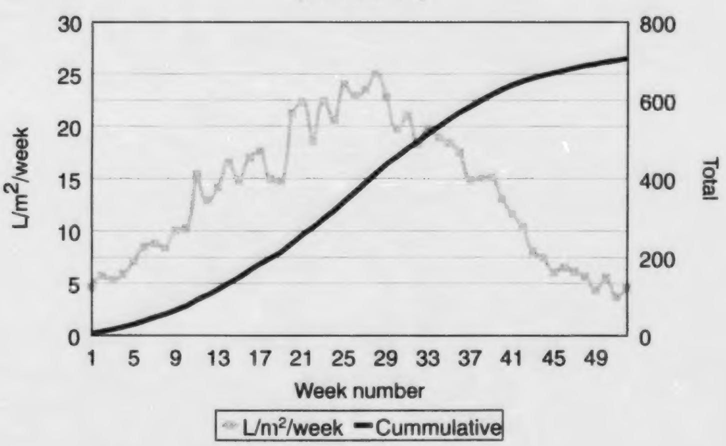
The quality of irrigation water is more important in hydroponic/soilless culture than in soil. Always consider water quality when establishing a fertilization program. For example, if the water contains large amounts of calcium or magnesium, the rates of calcium nitrate and magnesium sulphate should be reduced accordingly. Any nitrogen lost because of these adjustments can be made up by increasing the amount of another nitrogen-containing fertilizer. Note that certain trace elements such as iron, zinc and manganese can be high in some water supplies.

Use water with sodium and chloride levels below 50 ppm and 70 ppm respectively to create feed schedules for greenhouse vegetable crops. Avoid water containing higher levels (e.g., 100 ppm sodium or 140 ppm chlorine). Alternative water sources must be sought or a water purification system, such as reverse osmosis must be used. Tomato crops may be grown in nutrient solution containing 100 ppm chloride without too much difficulty. However, it is best to select a water source that is low in these 2 elements.

When using rain water, the usually low level of bicarbonate is raised by adding potassium bicarbonate to the water (not to the stock solutions). When the bicarbonate in the water supply is higher than 60 ppm, add phosphoric and/or nitric acids to adjust to the proper pH.

In areas where no municipal or lake water source is available, consider a cistern or a pond for collection and storage of rain water. Remember, more water is used in year-round crop production than the yearly rainfall that can be collected from the roof of a greenhouse range. This means that an additional water source is required when using a cistern to collect all of the rain from the roof during the year. To meet the needs of a fully-grown crop, the irrigation system must be able to deliver at least 8 L/m^2/day. Some fully-grown greenhouse crops (e.g., cucumbers) may require up to 5 litres of water per plant per day during the sunny, summer months. [See Figure 2–7, *Water Application in Greenhouse Vegetables*]

FIGURE 2–7. Water Application — Greenhouse Vegetables (L/m^2/week)



Location: GPCRC (Harrow)

3. Analytic Testing

Since hydroponic systems have a lower buffer capacity, all fertilizers are available to the crop. This means that any errors while applying the fertilizer are seen immediately. As a result of the current use of hydroponic production systems for greenhouse vegetables, growers need greater precision in applying fertilizers to their crops.

In general, an OMAFRA accredited laboratory for greenhouse media and nutrient solutions is used to conduct the tests. Prices vary between laboratories, as does the service and reliability. Choose a laboratory that provides good, reliable, quick service. The use of on-site testing kits varies as most growers prefer to use the reliability aspect of commercial labs. While it is acceptable to use colormetric kits and single element testing units to check some nutrients more regularly, defer to the results obtained from the lab tests.

Water Solution and Analyses

Conducting frequent and regular nutrient solution analysis allows trends in the nutrient levels to be detected before problems arise. Submit samples of the nutrient solution applied to the crop, together with samples present in the root zone/growing media.

Weekly or biweekly analysis of the:

- feed solution (solution applied to the crop) and
- root zone solution (solution extracted from the bag) and
- leachate (captured solution leaching from the bag)

provides a check to ensure the correct fertilizer is applied. It also indicates what adjustments are necessary to compensate for the plant consumption.

Weekly analysis of the NFT solution from the reservoir provides similar information. The tests conducted must analyze for both macronutrients and micronutrients at all times.

Tissue/Foliar Testing

These tests provide information regarding the nutrient status of the crop. Regular testing reveals trends and corrective measures can be implemented before problems arise. At every 3rd or 4th nutrient/water test, conduct a foliar analysis.

Each crop has a specific leaf that is used for analysis:

- Tomatoes — the 5th leaf from the growing tip on the main stem
- Cucumber — the 3rd leaf (10 cm across) from the growing tip, or from a lateral near the upper part of the crop canopy once topping has occurred
- Peppers — a young, fully expanded leaf about 15 cm from the growing tip
- Lettuce — a mature leaf

Wrap the leaf samples in a paper towel, place in a plastic bag, seal, and place in a standard brown envelope. This may be mailed or shipped by courier to the lab.

Table 3-1, *Guide to Nutrient Content of Leaf Tissue,* provides a guide to the normal acceptable range for greenhouse vegetables.

Soil Testing

In soil-grown greenhouse vegetable crops, conduct soil testing prior to planting to determine both the preplant and post-plant fertility program. Regular testing during the season is essential to ensure crops have received adequate fertilizer.

Soil samples should be representative of the soil type in the greenhouse. During the growing season, a regular soil analysis every 2 weeks helps maintain the ideal fertility program. Using a soil probe, samples should be taken from several locations in the greenhouse to a depth of 20 cm. Pool and mix these samples together, and forward this mixture to the lab for analysis. Taking separate samples where there are different soil types, or a specific problem area exists, allows for customized fertilizer programs for these locations.

Table 3-2, *Guidelines for Greenhouse Growing Media Analyzed by the Saturated Paste Method,* outlines acceptable nutrient levels in the soil and is a guide for subsequently adjusting the fertility program.

TABLE 3–1. A Guide to Nutrient Content of Leaf Tissue

	Tomatoes	Cucumbers	Peppers	Lettuce
Major Elements (%)				
Nitrogen	4.0–5.5	4.0–6.0	3.5–5.5	4.0–5.0
Phosphorus	0.3–0.65	0.6–1.0	0.4	0.6–0.8
Potassium	3.5–5.0	3.5–4.0	5.0–5.9	7.8–13.6
Calcium	1.6–3.2	2.4–3.2	2.8–3.2	0.8–1.2
Magnesium	0.36–0.5	0.36–0.5	0.5–0.75	0.25–0.5
Sulfur	1.3	0.3	0.5	0.3
Minor Elements (ppm)				
Manganese	55–165	55–165	55	55–110
Copper	5–10	7–12	5–10	6
Zinc	30–50	40–60	30–60	30
Boron	55–75	55–75	55–75	45
Iron	85–110	85–110	112	85–110

TABLE 3–2. Guidelines for Greenhouse Growing Media Analyzed by the Saturated-Paste Procedure

Analysis	Low	Acceptable	Optimum	High	Very High
Soluble salt, mS/cm	0–0.75	0.75–2.0	2.0–3.5	3.5–5.0	5.0+
Nitrate–N, ppm	0–39	40–99	100–199	200–299	300+
Phosphorus, ppm	0–2	3–5	6–10	11–18	19+
Potassium, ppm	0–59	60–149	150–249	250–349	350+
Calcium, ppm	0–79	80–199	200+		
Magnesium, ppm	0–29	30–69	70+		

4. Growing Media

The growing media must provide four basic needs for the plant: water, nutrients, oxygen and support for the roots. Over the past decade, there has been a major shift from soil culture to hydroponic/soilless culture. Today, most greenhouse vegetables are grown in rockwool (77%), Nutrient Film Technique [NFT] (12%) and other media such as coconut, foam, expanded clay pellets, peat, sawdust (1%). Traditional soil culture accounts for only 10%.

Rockwool Culture

Rockwool is an artificial growing media made from basaltic rock, coke and limestone. The basaltic rock is melted in a kiln and the molten rock is spun in threads that are layered to form mats. These are used as insulation in buildings, pipes, or for horticultural purposes. Horticultural rockwool is manufactured under strict guidelines to create a uniform product of specific density, treated with a wetting agent, and wrapped and sealed in polyethylene bags.

Horticultural rockwool:

- is sterile (free of pathogens, weed seeds, etc.),
- has a low cation exchange capacity/or is inert and does not interact with the nutrient solution
- has a high water holding capacity
- usually has a high initial pH
- is light weight and easy to handle
- allows for a shorter between-crop interval.

Rockwool is a free–draining media, and as such, it is important to lay out the production system properly within the greenhouse to ensure uniform watering to all plants. If not set up properly, some bags may remain wet, restricting plant growth and causing lack of uniformity in the crop.

A basic rockwool production system consists of a:

- ground sheet that isolates the soil surface from the greenhouse growing environment
- styrofoam strip for insulation (placed underneath the rockwool slab and either above or below the ground sheet),
- drip irrigation delivery system, and
- leachate collection system.

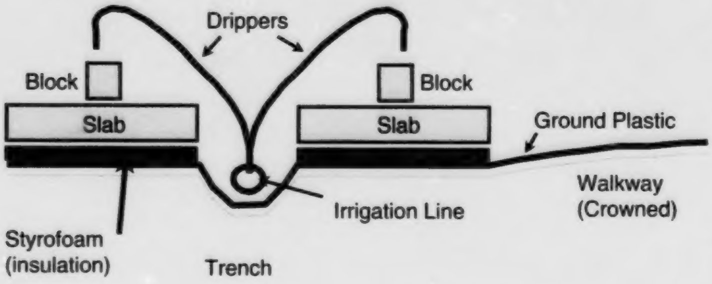
Rockwool is available as slabs, blocks, starting plugs, as well as granules. The granules are used as an additive to peat bag culture to form peat wool or on their own. Granule bag culture is not as popular as the slab rockwool culture. Seed is sown in the rockwool starting plugs and after germination, transplanted into the rockwool blocks. Plants in the rockwool blocks are transplanted onto the rockwool slabs in the greenhouse once they have reached the desired size and stage. This process can take up to 6–8 weeks for tomatoes, 3–4 weeks for cucumbers and 7–9 weeks for peppers. This period is longer during the winter and shorter in the summer.

There are two methods of setting up rockwool culture: open system or closed system.

Open System

In this system, the leachate solution is allowed to run to waste. The soil in each greenhouse is contoured to create a trench between the plant rows, a slight crown along the length of the walkways, and the site of the rockwool slab is level or on a slight slope (i.e., < 0.5%) towards the trench. The trench acts as a drain to collect the nutrient solution. Traditionally, a ground sheet is placed over the contoured soil and the drip irrigation system is placed in the trench for convenience. See Figure 4-1, *Layout for Open System Rockwool*, for a diagram of the basic system.

FIGURE 4-1. Layout for Open System Rockwool



Closed System

In this system, the leachate solution is collected, treated and re-used to irrigate the crop. The basic set up is similar to the open system, but the drain trench is sloped at 0.5% towards one end of the greenhouse. The base of the trench is lined with plastic. A perforated flexible plastic tube is placed in the bottom of the trench that is then backfilled with clean pea gravel up to ground level, and covered with ground sheet plastic. [*Plate 1*] [See Figure 4-2, *Layout for Closed System Rockwool*]

The size of the flexible plastic tube is determined by the size of the trench. In most cases, a 5 cm (2 in.) diameter plastic tube is sufficient to collect and rapidly drain the leachate water. Rockwool slabs are placed at their specific location, and at every drain hole for the slab, a slit is made in the ground sheet plastic to allow for the leachate to escape into the flexible plastic tube. The tube is hooked with a 10 cm (4 in.) sewer pipe that drains to a reservoir where the leachate is stored, and treated before being reused to irrigate the crop.

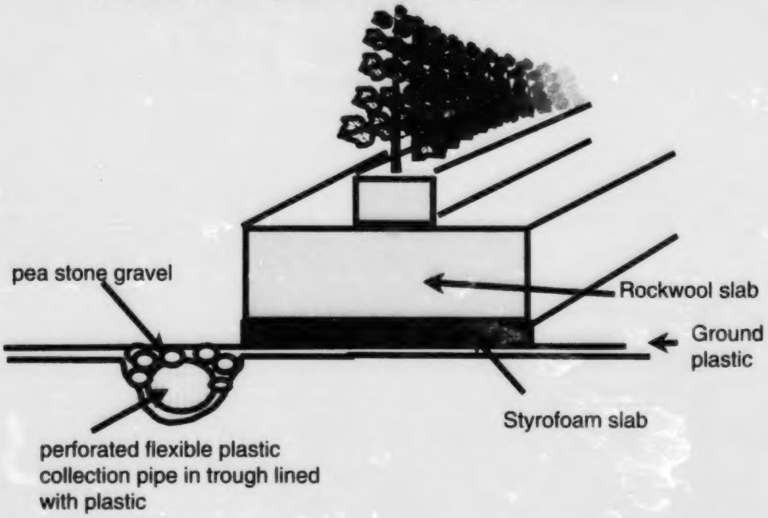
Numerous other techniques can be used to capture the leachate. For example:

- flexible plastic sleeves with brackets to keep the rockwool slabs out of the leachate water
- styrofoam shaped to hold the slab with a deeper groove to channel the leachate water away
- preformed aluminum troughs with ridges in the base that channel the leachate
- preformed plastic troughs with leachate drainage channels formed at the base to allow the solution to be captured.

There is an increased trend by growers to use the "V" system, where a single row of rockwool slabs with double the number of plants is placed in the centre of the growing row. The plants are alternately trained to opposite sides of the growing row to form 2 plant rows. This decreases the amount of rockwool required to grow a crop, although it requires an irrigation system capable of delivering 150–200 mL/plant/cycle every 15 minutes.

The raised trough system, [*Plate 2*] while presently at the trial stage in Ontario, is increasing in popularity. In this system the rockwool slabs are placed in preformed raised troughs, 80–120 cm off the ground, either on stands or hung off chains from the trusses of greenhouses engineered to hold this load. The rockwool used in this system is usually half the length (50 cm) and slightly wider (20 cm). The number of plants per slab is doubled (same as in "V" system) and the leachate water is collected, treated and re-used. The rockwool slabs are spaced one slab apart to allow the addition of new slabs for the next crop.

FIGURE 4–2. Layout for Closed System Rockwool



This system lends itself to intercropping, where the new crop is planted as the old crop is coming to an end. The final harvest of the old crop coincides with the first harvest of the new crop.

The advantage of a closed system, where the leachate is recycled is improved fertilizer and water use efficiency.

After placing the slabs in the greenhouse, the plant location is marked and a round or square hole is cut in the plastic overwrap. Hole size is determined by the size of the rockwool block used. The rockwool itself is not cut. Only the plastic bag is cut to expose the rockwool slab. Prior to transplanting the crop onto the rockwool slabs, a complete nutrient solution is applied to soak the bags thoroughly.

The drip irrigation emitters are placed onto each hole and the irrigation is started.

Water Management

Rockwool slabs, although free draining, can become waterlogged. This is especially critical during early plant growth stages, and under low light conditions. Set the bags up properly for optimum drainage.

CAUTION: The degree of dryness is dependent upon the characteristics of the slab purchased. Some slabs are characteristically dry and this procedure must not be practiced, or if conducted, must be done so with great care.

After placing bags in the greenhouse, the bags are saturated with a complete nutrient solution. [See individual crops discussed in Sections 6, 7, 8 and 9 for specific solutions]. The bag must be completely saturated to activate the wetting agent, ensuring that the whole slab is available to the plant roots. After planting, a slit is cut in the bag from the bottom up to allow for drainage. (Figure 4-3, *Drainage Slits on Rockwool Slab for Cucumber)* This is usually done within 24–48 hours after planting. The plants are watered for ½ hour and then no further nutrient solution is applied for 2–3 days, depending on the weather. This ensures rapid root penetration into the slab as well as allows for the slab to dry out. After 2–3 days, a 15–minute watering period followed by 2–3 days no water (depending on weather) is conducted.

Subsequently, watering is conducted as required and the amount of water applied to the crop is determined by several factors:

- stage of plant growth
- light
- temperatures in the greenhouse and in the slab
- RH/VPD in the greenhouse
- amount of air movement

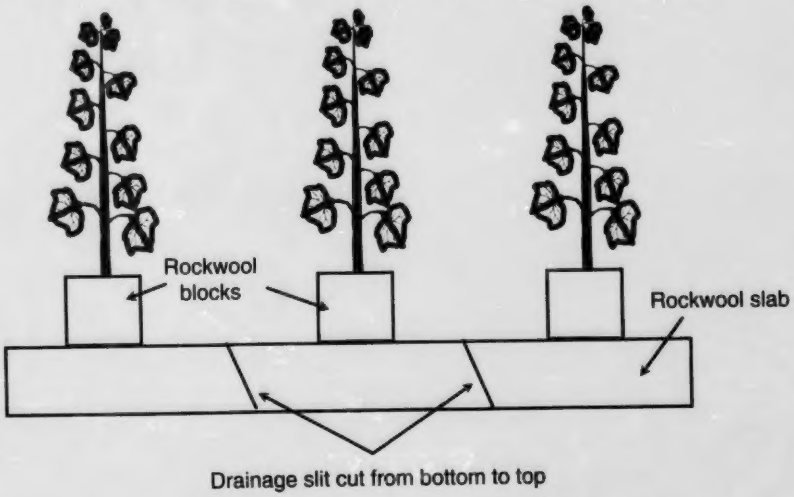
In general, a 100 mL/cycle is used. This may vary, depending on:

- the type of rockwool,
- stage of plant growth,
- time of year,
- Electrical Conductivity (EC), a measure of the quantity of fertilizer present in the solution, and
- percentage drain.

To determine the correct watering pattern, monitor both the EC in the slab, as well as the percent drain/leachate. Use a large bore hypodermic needle attached to a 50 cc plunger to extract the nutrient solution from the slab. Measure the EC using an EC meter or EC pen.

As well, the percent leachate is monitored. This is achieved by placing 1 or 2 slabs in a tray with a drain,

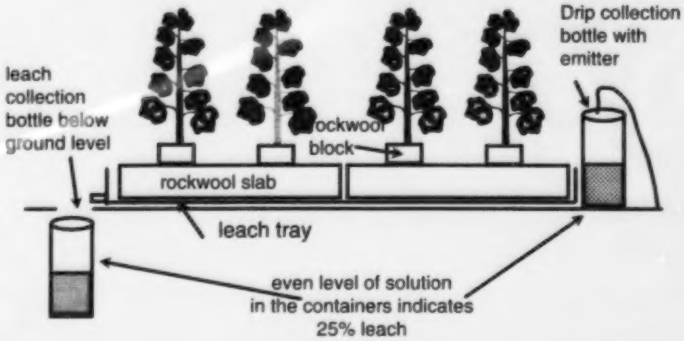
FIGURE 4-3. Drainage Slits on Rockwool Slab for Cucumber



and measuring the amount of water that is collected. Usually a leachate or overwatering of 20%–30% is recommended. The percent leachate may be measured electronically or simply by comparing what is added and what is leached out.

The simplest way is to collect the solution applied from a single emitter into a 4L graduated container and the leachate from 4 plants in a similar sized and type of container. If the two levels are the same, the rate of leaching was 25%. [Figure 4-4, *Leachate Measurement*] This measurement should be conducted at the same time daily, usually before the first watering. This allows the watering to be adjusted to obtain the proper root environment.

FIGURE 4-4. Leachate Measurement


Drip collection bottle with emitter
leach collection bottle below ground level
rockwool block
rockwool slab
leach tray
even level of solution in the containers indicates 25% leach

A daily record of the amount of leachate, and irrigated water must be kept. As well, the EC and pH of the irrigation water and the slab must be recorded.

Night watering is usually not recommended. Start the irrigation cycles 1–2 hours after sunrise and end them 1–2 hours before sunset. After the first irrigation cycle, check the slabs for leachate. If there is no leachate after the 3rd cycle the bags are too dry. Extend the irrigation program later into the evening or start earlier in the day. If there is leachate after the first cycle, the slabs are too wet. Either delay start-up time or end irrigation earlier.

If the irrigation program is not properly set up, the slabs may be:

1. **too wet** – resulting in:
    - poor aeration of the slab
    - softer vegetative growth
    - poor root growth
    - increased root disease
2. **too dry** – resulting in:
    - damaged root hairs
    - high EC
    - problems with calcium uptake and movement (Blossom end rot (BER) in tomatoes and peppers, leaf scorch/curl on young cucumber leaves)
    - harder growth, thinner plants
    - dark, smaller, thick leaves

Use either time, start tray or accumulated light radiation to initiate the irrigation cycles.

The rockwool slab water control, EC and temperature may be measured using a unit available commercially. These units are portable and can measure data from several slabs at any time of day and night. The latest models are permanently installed and recorded data are sent directly to the irrigation computer, where adjustments to the irrigation schedule are made.

Fertilizer Schedules

Generally, when used the first time, rockwool slabs tend to have a high pH. Apply a nutrient solution at pH of 5.0–5.5 to allow for this high pH. It usually takes some time before the pH will remain at the desired pH of 5.8. As the rockwool slab is inert, apply a complete nutrient solution at all times. Consult individual crops discussed in Sections 6, 7, 8 and 9 for suggested fertilizer schedules.

Slab Sterilization

While rockwool slabs may be used for multiple crops, make sure to sterilize the slabs in-between crops Shortly before (24–36 hours) the crop is terminated, decrease the amount of water applied and allow the plants to dry out the slabs. Once the slabs are dry, and the plants removed, remove the plastic wrap and stack the slabs on pallets. [*Plate 3*] Leave adequate space between slabs for steam to penetrate. Do not stack slabs more than 1 m high to prevent damage to the bottom slabs. Cover the stack of slabs with plastic and introduce steam. [*Plate 4*] Apply a temperature of 90°C for 30 minutes, measured in the middle of the stack, to disinfect the slabs. To ensure good steam penetration, steam the slabs overnight. Let slabs cool, then wrap in new plastic, seal, and place in the greenhouse ready for the next crop.

Nutrient Film Technique (NFT)

Nutrient film technique (NFT) is a method of growing plants in a continuous shallow flow of nutrient solution. This technique is a true hydroponic culture, where the bare roots of the plants are bathed in a nutrient solution that is recycled in a closed system. This saves both fertilizer and water, and reduces the impact on the environment.

The basic design consists of a reservoir tank and its various components of pumps, solution delivery network, growing troughs and solution return system. The nutrient solution is pumped from the reservoir to the top end of the growing trough, flowing by gravity to the return line and back to the reservoir. The growing trough is set on a slope of 1%–2% to facilitate the flow of the nutrient solution.

The Reservoir Tank

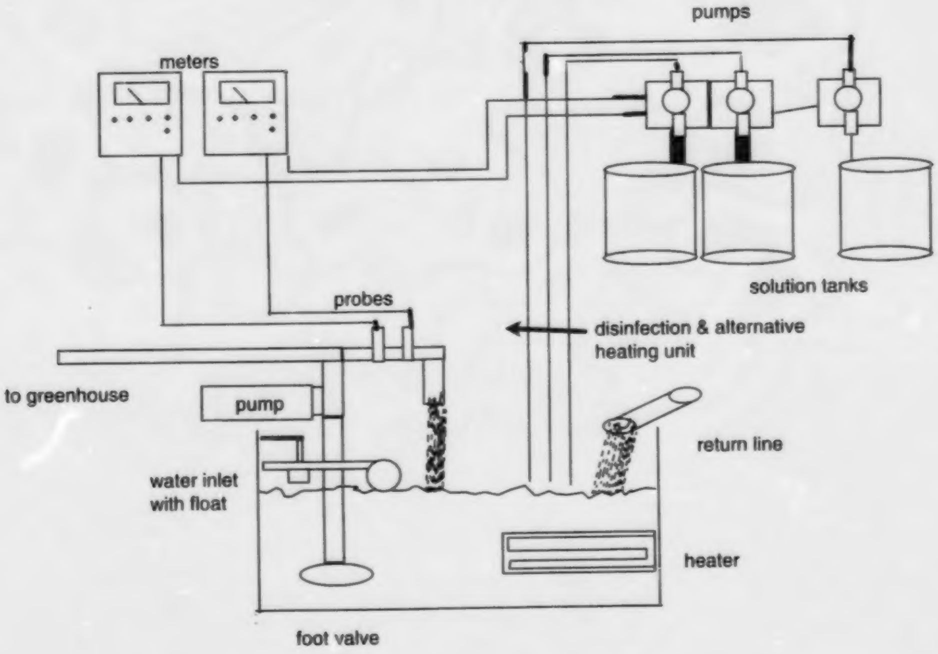
The reservoir tank for an NFT system is located below grade to allow for a gravity-fed return flow of the nutrient solution. [See Figure 4-5, *NFT Tank Setup*] It may be constructed of:

- concrete blocks
- poured concrete formed into a tank
- concrete crocks buried in the ground, with a cement floor
- rigid plastic tanks buried in the ground or placed as inserts in concrete casings
- a pit with wooden walls lined with a swimming pool liner

The concrete must be painted with a rubber-based, non-phytotoxic paint to protect the concrete from the nutrient solution.

The reservoir tanks usually have a 5,500 L/0.5 ha (1000 gal/acre) capacity with 4,000–4,500 L (750 gallons) of water in the tank. The traditional NFT system has approximately 13,500–13,750 L or 3,000 gallons/ 0.5 ha in the greenhouse. Provisions may be made to store this water in case of electrical power failure or it may be drained. The tank is equipped with an automatic fresh water intake that allows fresh water to flow into the tank once the level drops below a set amount.

FIGURE 4-5. NFT Tank Setup



Pump System

The pumping system must be able to deliver a high volume of water (at least 2 L/emitter) at a low pressure, be reliable, and equipped with stainless steel or plastic impellers and components. Normally, systems are designed based on a 5 HP pumping station/acre. A standby pump of equivalent capacity equipped with a sensor to automatically switch it on must also be installed.

A more economical technique is to install 3 pumps of 2 HP each in parallel, all running at once. If one of the pumps fails, the 2 remaining pumps are capable of supplying enough solution to the crop to minimize crop injury while repairs are conducted. As a safety feature, keep a spare motor to replace the malfunctioning motor. As electrical disruption can cause crop devastation, all facilities require a standby electrical generator designed to provide adequate electricity to power the pumps and other essential greenhouse features (e.g., heat, vents, computers, etc.)

An added benefit of using three, 2 HP pumps is that the extra pumping capacity allows one to increase the solution flow rate of 2 L/min./trough if required. As well, the extra capacity can be used to aerate the tanks, send the nutrient solution to the in-line monitoring system, and for heating and pasteurization systems. This removes the need for an extra pump to supply nutrient solution for these purposes.

pH and EC Controllers

The solution pH and EC (electrical conductivity) is continuously monitored by in-line probes, and adjustments made automatically. Once the reading varies from the grower established set point, pH and EC controllers trigger the attached nutrient solution dosing pumps. [see Figure 4-5] This system adds fertilizer and acids on a continual basis as required. A time-out switch on the controllers prevents over-dosing. This is an important safety feature, as excessive fertilizer or acid can be detrimental to the crop. As a safety measure, a second set of pH and EC monitors that can act as a check on the primary controllers are installed.

A computerized fertilizer injector system (e.g., Harrow Fertigation Manager®) can also be used to monitor and adjust the nutrient solution. The advantage of such a system is that it can:

- monitor several NFT reservoir tanks from a single unit,
- maintain the integrity of the nutrient solutions for each NFT system
- allow for different feed schedules (e.g., older crops vs. younger crops) to be maintained in each system.

Heating

The optimum solution temperature is 18 °C –21°C. Usually, the solution temperature reflects the air temperature. An additional heating source to maintain a constant solution temperature is necessary, especially when adding fresh water. Stainless steel hot water heating coils are placed in the reservoir tank or, as in most cases, in a small auxiliary tank. The nutrient solution is supplied to the auxiliary tank off the main pump on a side loop and allowed to return to the reservoir tank after heating.

As the temperature of the nutrient solution increases, the dissolved oxygen in the nutrient solution decreases. This may become a problem in the summer, especially when planting a fall crop. The young plants initially do not provide adequate shade. This allows the radiant energy from the sun to heat the nutrient solution. Temperatures as high as 30°C are not uncommon. Well water is used to cool the nutrient solution.

Pasteurizing Nutrient Solution

A pasteurization loop is installed on the NFT system to allow 25% of the nutrient solution to pass through UV lamps back into the reservoir tank. A complete sterilization of the nutrient solution is not recommended because a sterile solution allows rapid proliferation of microbial populations. A partial pasteurization, while helping maintain a lower microbial population, allows a balance between beneficial and non-beneficial microbial populations to be established in the solution.

Ozonation is another method that may be used to disinfect the nutrient solution. However, this requires specialized customized systems to avoid plant injury and ensure efficiency. This is for the adventurous grower and, as of printing, no installation in Ontario uses this technique.

While slow sand filtration is an effective technique, it cannot provide the volume or the flow rate necessary for an NFT system, and thus is not used at present.

Aeration

The nutrient solution must be aerated. A large drop between the return line and the level of solution in the tank provides good agitation and helps replenish the oxygen. An aeration loop, using a venturi system, also improves oxygenation by forcing air into the nutrient solution. Injecting oxygen into the nutrient solution is another way to maintain adequate O_2 levels.

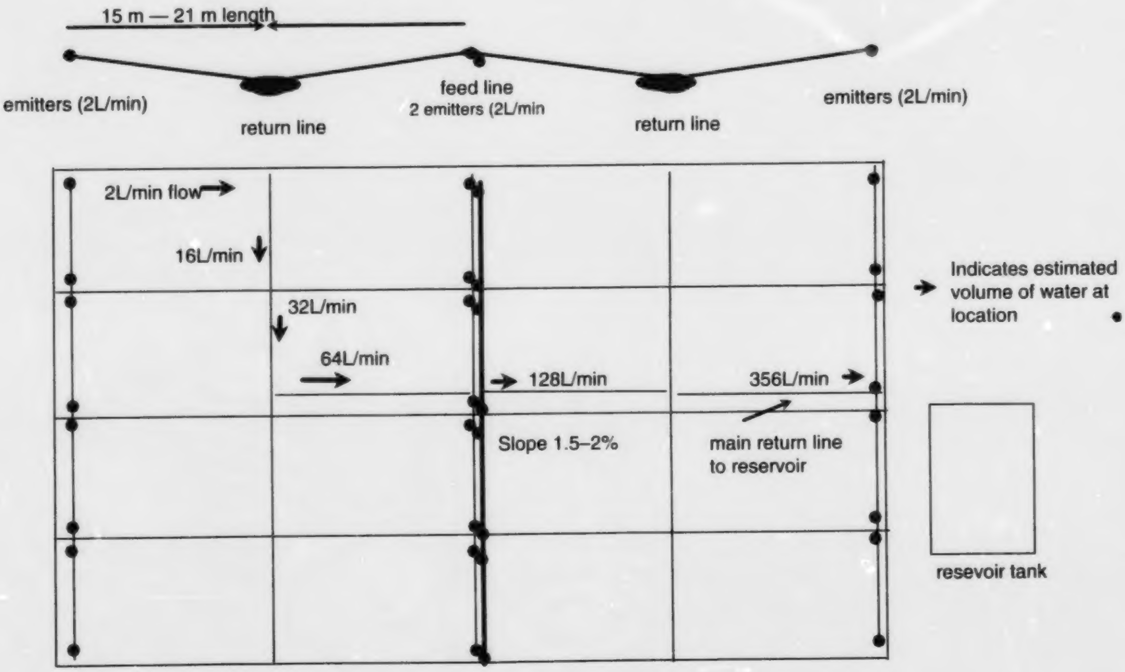
Plumbing–Nutrient Solution Distribution and Collection

The nutrient solution delivery system must be designed to ensure that all troughs receive the same flow rate (2L/min./trough). [See Figure 4-6, *Layout for NFT Emitters and Return Line*] A 75 mm (3 in.) main header from the pump set delivers the nutrient solution to 37.5–50 mm (1.5 – 2.0 in.) subheader. The subheader delivers the solution to a 19–25 mm (0.75 – 1.0 in.) sub-subheader at each zone from which a 4 mm flexible tube (35–40 cm long) delivers at least 2 L/min. nutrient solution per trough. A well-designed system will require little or no balancing between zones to ensure even water distribution. PVC is used for all plumbing components as the nutrient solution can corrode galvanized pipes resulting in phytotoxicity.

The intakes for the pumps are usually located near the bottom of the reservoir tank and will require a basket filter with a one-way check valve at the bottom. This is crucial in case of a power failure, as the pumps do not need to be primed once the generator restores electricity.

The return line is buried in the ground and consists of 10 cm (4 in.) sewer pipe (inexpensive, easy to install and durable). Holes cut into the pipe or "T" junctions located at every trough return location allow the solution to flow from the growing trough into the return line. The solution flows by gravity to the reservoir tank. A 0.5% slope is usually adequate. A large drop between the return line and the top of the nutrient solution is necessary to ensure maximum mixing of the return solution with that of the reservoir. The increased agitation enhances solution aeration helping to ensure adequate oxygen for the root system. As well, baffles placed at the end of the return line may also increase agitation to improve aeration. A coarse filter (e.g., a nylon stocking placed over the opening) will trap any root pieces etc. that may clog the pump impellers.

FIGURE 4-6. Layout for NFT Emitters and Return Line



Growing Trough

Numerous types of troughs are available. These vary from aluminum troughs with plastic covers, preformed rigid plastic troughs with flaps, to 6–mil white on black polytubes. In all cases, the purpose of the trough is to provide a channel for the nutrient solution to flow and the roots to grow in. The least expensive system is the 6–mil poly tube laid on 4 cm (2 in.) styrofoam (20 cm wide). A wide shallow groove running along the length of the styrofoam channels the nutrient solution towards the middle of the trough. This is especially important in the early stages of the cropping cycle to ensure that all plants receive nutrient solution. However, too deep a channel results in poor aeration, decreasing the amount of oxygen available to the roots, decreasing performance and encouraging root die-back and diseases.

Ideally the trough should have a slope of 1.5%–2%, be 15 m (50 ft) long and 30 cm (12 in.) wide at the base. Do not have the trough longer than 21 m (70 ft.) without modifying the design of the system.

Phytotoxicity

It is important to ensure that all components of the NFT system are non-phytotoxic. Do not use metal components (galvanized pipes or copper pipes) as they will corrode and release micronutrients, such as zinc or copper, which will accumulate to toxic levels. Plastic components in the irrigation lines, as well as the growing trough, must be non-phytotoxic. Components in some flexible plastics are extremely toxic to plants.

Soil Culture

The number of growers producing in this medium has decreased. However, some smaller greenhouse operations in isolated areas continue to produce good greenhouse vegetable crops. Drip irrigation or tape irrigation is commonly used to grow soil crops in the greenhouse.

Type of Soil

A well-aerated soil with good drainage, rich in nutrients, high in organic matter content and free of pathogens is needed to achieve maximum production. Soils most suited are loam, sandy-loam and some silty loam types. Other soil types may be used but require proper management and increased input costs to achieve maximum productivity. For example, early winter production in a heavy clay soil requires installation of tile drains, increasing organic matter content before the cropping season to aggregate soil particles, and careful water and nutrient management to achieve success. Sandy soils with poor water holding capacity require frequent watering (with nutrients), which leads to increased potential for ground water contamination. This problem can be overcome with a collection system designed to catch and recycle the excess water.

Drainage

A well draining soil is best for greenhouse vegetable production. A tile drainage system installed in ground beds ensures all excess water is carried away. Contact a local agricultural drainage company to help design the system. Generally, a 10 cm. diameter tile 35 cm deep and 45–60 cm apart with a slope of 10 cm in 150 m is adequate.

Flooding and Leaching

Prior to planting the soil is cultivated to bring it to field capacity. The amount of water required to do this varies depending upon the soil type and the soil moisture content at the time. In general, use 20–50 L/m^2. Water leaching (100 L/m^2) may be necessary in some soils, especially those that were steam pasteurized, to lower high levels of ammonium and manganese.

Soil Pasteurization

Harmful pathogens (bacteria and fungi) are present in most soils, along with weed seeds and insects. Soil pasteurization will eliminate them. Soils should be in fine tilth to allow rapid, uniform penetration of the steam or fumigant. Large clods or lumps of dirt and undecomposed crop remains (stem and root) may hinder full penetration.

Temperatures of 60°C for 30 min. under ideal conditions eliminates most organisms (except viruses) of concern to the grower. [See Table 4-1, *Time-Temperature Requirements to Destroy Undesirable Organisms*] Over-heating (above 82°C) eliminates beneficial organisms as well, and causes the soil to become sterile and subject to a greater degree of infection than previously.

Other undesirable side effects are:

- excessive ammonia release
- manganese toxicity

- destruction of organic matter
- higher total salt level

TABLE 4–1. Time—Temperature Requirements to Destroy Undesirable Organisms

	Time (min.)	Temperature (°C)
Weeds(most)	15	70 – 80
Insects+ mites	20	60 – 71
Bacteria (most)	10	60
Fusarium	30	57
Botrytis	15	55
Nematodes	15	55
Rhizoctonia	30	50
Sclerotina	5	50
Pythium	40	46

Greenhouse soils can be steam pasteurized by injecting steam through agricultural tile drain (top of the tile 30–40 cm below the soil and 46–60 cm centres). Covering the soil surface with a plastic sheet to trap the steam in the soil greatly enhances its effectiveness. Alternatively, if the drain tile is in disrepair, steam can be injected directly under a specially formulated plastic steam tarp. The edges of the tarp are buried 10–12 cm so that the steam, injected at 41–48 kPa (6–7 psi) pressure can be confined. The temperature of the soil must be monitored to ensure that an adequate temperature has been achieved to pasteurize the soil and that it is not under or over heated. (Always leach the soil after steam pasteurization.)

Chemical fumigants may also be used, although the choice is limited. Follow manufacturer's label direction for rate, duration and venting periods to safely, and effectively use these products.

Organic Matter

A high level of organic matter helps maintain a stable soil structure and improves water holding capacity and aeration of the soil. Coarse peat at rates as high as 500 m^3/ha may be applied to new soils to improve their condition. Peat is acidic (pH 4.0) and lowers the pH of the soil. This is a benefit for alkaline soils but must be corrected in acidic soils by adding lime (5 kg of limestone/m^3 of peat).

The decomposition rate of organic matter in greenhouse soils is quite high. Apply an annual rate of 100 m^3 of peat per hectare. Incorporate both peat and lime in the soil prior to the main cultivation. Composted manure may be incorporated to aid organic matter content management but losses due to weed and herbicide contamination may cause severe crop losses.

pH Control

Greenhouse vegetables grow reasonably well within a wide range of soil pH (5.5–7.5) but a pH of 6.0–6.5 for mineral soils and 5.0–5.5 for organic soils is generally accepted as optimum. Use either ground calcitic limestone (3 tonnes per ha for each 0.5 pH unit increase for most light soils) or dolomitic limestone (if soil magnesium level is low) to raise the pH of the soil to the desired level.

Adding peat to the soil for organic matter amendment lowers the pH of high pH soils. Apply annually to make up the loss due to decomposition. Alternatively, add elemental sulphur (flowers of sulphur) at 50–100 kg/ha for each 0.5–1.0 unit of pH decrease. Or apply ordinary sulphur to the soil and incorporate into the top 15–30 cm of the soil. Do this several weeks before planting. The reaction will be slow on cold soils. The amount of sulphur will vary from soil to soil depending on the buffering capacity (exchange capacity) and the original pH of the soil.

The pH of the soil around the plant roots is more critical. Adjusting the pH only at the plant site can easily be accomplished when drip irrigating the crop with a complete nutrient solution at pH 5.5 using phosphoric and nitric acid. This will maintain clean irrigation lines and drippers, as well as lower the pH around the root zone enhancing plant growth.

Drip Irrigation

This system:

- allows a regulated control of water and fertilizer to the crop,
- reduces humidity of the greenhouse
- allows the use of white polyethylene film as a light reflecting mulch, and
- keeps the product clean.

The irrigation system is designed to deliver nutrient solution to each plant through series of pipes with in-line emitters or hose-end drippers at 2 L/hr. A nutrient solution containing all the required fertilizers is applied 3–4 times per day to meet the water and nutrient needs of the plant. Adjustments to the fertilizer composition (type of fertilizer and quantity) and the volume of water applied will vary depending upon the type of crop grown, stage of crop, time of the season, light level, temperature of the greenhouse, and the water holding capacity of the soil. Daily evaluation of the soil condition approximately 10 cm away from the plant and 10–15 cm deep will assist in determining initiation and duration of the irrigation cycle. The pH and the electrical conductivity measurements of this sample will also help in establishing fertilizer status of the soil.

The soil sample is mixed with tap water (1 part soil to 2 parts water) and the pH and electrical conductivity are measured. A pH reading of 5.5–6.5 and an electrical conductivity reading 0.9–1.2 mS/cm is considered ideal. Information from these quick home tests will assist in determining the amount of fertilizer and water required by the crop.

A laboratory soil analysis of a composite soil sample taken from several locations in the greenhouse helps set the required fertilizer schedule. In the early stages of the cropping cycle, conduct this analysis weekly and every 2–3 weeks after that. More frequent testing may be necessary if crop production problems occur.

5. Plant Raising

A proper start at this stage of the cropping cycle is essential to obtain a uniform, high yielding crop that produces a good quality product. A poor start invariably results in a poor or less than satisfying finish, requiring extra work to obtain a good crop and results in lower economic returns. There are three critical phases:

1. seed
2. sowing and germination
3. transplant raising to a finished product

Seed

Use seed of the highest quality to ensure a good start. Most seed supplied to the greenhouse vegetable industry has been cleaned, usually treated, and tested for germination/viability. This information is usually printed on the package or is available from the seed supplier. The germination test is conducted by a certified seed laboratory and is performed under strict, standardized guidelines. Germination is defined as the emergence of the radicle from the seed coat. In most cases, the percent germination varies from 75%–90% for tomatoes, 95% for cucumber, 85%–95% for peppers, and 95% for lettuce. Germination percent may vary dramatically depending upon the growing conditions where the seeds were produced. Thus, the number of seed ordered must be adjusted accordingly.

To the grower or plant raiser, a more critical value is the percent emergence — defined as the ratio of the number of seedlings emerged from the growing media to the number sown. This value may vary quite dramatically and is influenced by numerous factors:

- seed vigour
- depth of sowing
- moisture of media
- media aeration
- media temperature.

The difference between percent germination and percent emergence may vary as much as 10%–20%.

Note that rate of seed germination varies dramatically, with some seeds germinating very rapidly while others are slower. Seeds can be grouped into 3 categories:

Category I	Category II	Category III
seeds emerge 2-3 days after sowing	seeds emerge 3-4 days later	seeds emerge later; have twisted cotyledons, blind shoots, etc.

The percent in each category varies with species, cultivar and seed quality, and fluctuates yearly. For example, the percent emergence may look like this:

Category I	Category II	Category III
73	10	10

The remaining 7% did not emerge.

Categories I and II are true emergence and only these are planted. To have an adequate number of plants, at least 25% more seeds are sown. This allows for some spare quality plants in case of loss due to handling, etc. In general, the following is suggested:

	# Plants Needed	# Seeds Ordered
Tomato	10,000	12,000–13,000
Cucumber	6,500	7,500*
Pepper	10,000	12,000–13,000
Lettuce	1,000	1,100–1,200

* Cucumber seed, in general, have a higher percent germination and emergence.

Sowing and Germination

Sowing seed is a simple but critical step of plant raising. A growing media with good drainage, water holding capacity and aeration such as rockwool or oasis plugs is ideal. These are available in various sizes, in styrofoam trays or plastic flats. If reusing, thoroughly disinfect before use.

Place seeds on the dimpled surface or in the hole of the plug and cover with medium vermiculite. An even sowing depth is essential to ensure uniform emergence and seedling development. Seed placed too deep in the growing media may take 2–3 days longer to emerge, and may be weaker and slower to develop true leaves. Seed placed on the surface is prone to drying out or in some cases the radicle may not anchor properly, causing seedlings to fall over.

Prior to sowing, pre-soak the growing media with clear water or a dilute complete nutrient solution (EC 1.0–1.5 mS/cm) at 20°C–25°C. After sowing, gently water the growing media to dampen the vermiculite. Ideally, place the flats/trays in a germination chamber or alternatively on benches with heating under the flat or bench heating. Cover the flats on the benches with a 2-mil clear polyethylene sheet to prevent drying out. [*Plate 5*] To ensure uniform, rapid emergence, maintain the ideal media temperature found in Table 5-1, *Germination Temperatures.*

After 60%–75% emergence occurs, remove either the flats/trays from the germination chamber or the poly cover. This is usually done 60–96 hr after seeding, depending on the type of crop and cultivar grown. See Table 5-2, *Approximate Hours for Germination.* If this change is carried out too early, emergence of Categories II and III seeds will be delayed and if too late, it will result in the stretching of the earlier emerged Category I seedlings. Once maximum emergence — more than 80% — occurs, gradually lower air temperature to 19°C for tomatoes (1°C/day in general), 21°C for cucumber and 20°C for peppers. Adjust temperatures according to light incidence (see Section 1, page 20, on Light) to obtain the plant at the desired time. Too large a day/night temperature fluctuation results in elongated plants.

TABLE 5–1. Germination temperatures

Crop	Temperature*
tomato	25°C
cucumber	27°C
lettuce	16–18°C
pepper	26°C

* Growing media temperature

TABLE 5–2. Approximate Hours for Germination

Tomatoes	
Good germination	72 hr
Poor germination	96 hr
Peppers	72–96 hr
Cucumbers	60 hr
Lettuce	72 hr

Once the true leaves emerge, water the flats with a complete nutrient solution, starting at 2.0 mS/cm EC, and gradually raising the EC to about 3.0 mS/cm prior to transplanting. Over-watering results in poor aeration of the media, creating inadequate root development. As well, excess moisture (especially applied as a mist) causes the root zone temperature to drop, delaying growth and increasing variability. If the media is too dry plant growth decreases, leaf size reduces, and the EC of the media increases. The weaker plants may not survive or if they do, will be more prone to disease incidences.

Transplant seedlings into rockwool blocks once they reach the desired size. Too long a period in the flats (more than 3 weeks for tomatoes and peppers, 1.5 weeks for cucumbers) results in overcrowding, stretching and weakening of the seedlings.

Supplementing with CO_2 and high–pressure sodium light improves growth and helps establish good roots.

- For CO_2, supplement to 1000 ppm under good light conditions. As seedlings are extremely sensitive, it is essential to use a clean CO_2 source, such as liquid CO_2.

- Supplementary light at 20 watts/m^2 using high–pressure sodium lights enhances seedling development. Apply an 18–hr photoperiod for tomatoes, peppers and lettuce, and a 24–hr photoperiod for cucumbers.

Transplant Raising

Seedlings are ready to transplant when the first true leaves have fully emerged and/or when the seedlings touch.

Average times are: tomatoes at 14–21 days, cucumbers at 10–14 days and peppers at 17–24 days.

The time required varies depending upon:

- the cultivar
- seedling vigor
- light
- temperature
- nutrition and
- moisture

A short sturdy seedling is desirable. A seedling with a thick stem, dark green leaves and a well-developed root system filling the plug is ideal. Pop the seedlings out of the tray using a plug popper. Prior to removing plugs, soak the trays with nutrient solution to allow the plugs to easily slide out of the tray. Handle the seedlings carefully. The stem may be very brittle or soft and easily damaged. Handle seedlings by the cotyledons.

Soak the rockwool blocks thoroughly with a complete nutrient solution (EC 2.0 mS/cm; pH 5.8) by dunking the blocks in a tub or by overhead watering before transplanting seedlings. It is important to soak the blocks thoroughly and uniformly to ensure proper seedling establishment. Dry blocks restrict root development and growth, increasing plant to plant variability.

Place seedling plugs in holes in the blocks. If, in some cases, the seedlings are too tall, fold the lower part of the stem into the hole and push the root plug down to fill the hole. This is a common practice for tomatoes, rarely for any other greenhouse vegetable. Roots will develop along the stem within the hole, anchoring the seedling and resulting in the cotyledonary leaves being closer to the surface of the rockwool block. This gives a sturdier transplant.

Place the transplants in trays (6–8 blocks/standard flat) and distribute in the starter house. To ensure good rooting, place trays on benches with bottom heat (or directly on heated concrete floors). [*Plate 6*] Transplants are ready for planting directly onto the rockwool slab or NFT troughs in the main production area when:

- tomatoes — 1st flowers are showing
- cucumbers — 4–5 true leaves
- peppers — when flower at first branching level is opening

If needed, support the plants using a 20–30 cm thin bamboo stake. This encourages development of larger transplants that are more easily handled and allows more time before plants need to be tied after transplanting.

Alternatively, new transplants can be moved directly into the production houses. Place the blocks on the rockwool slab beside the hole and the drippers in the block. Use the irrigation system to water the blocks. This method saves on labour, but costs more to heat the whole greenhouse operation.

After transplanting, maintain greenhouse temperature at 25°C, 24 hr/day for 4–5 days and then gradually lower the temperature. (See individual crop sections for specific temperature regimes.) In a starter house, supplementary lighting at 20 watts/m^2 and CO_2 at 1000 ppm increases the rate of root and shoot growth, resulting in earlier flower bud development. Keep a photoperiod of 18 hr for peppers and tomatoes and 24 hr for cucumbers. Since it is not cost-effective, plants placed directly into the main production greenhouse do not receive supplementary light. But they benefit from supplemental CO_2 —1000 ppm on sunny days and 400–500 ppm on cloudy days.

Water transplants with a complete nutrient solution starting at a low EC (2 mS/cm) and gradually increase (0.250 mS/cm/day) to 3 mS/cm, similar to emerged seedlings. Further increases in EC are determined by:

- the rate of plant growth
- available light
- temperature
- RH and
- moisture in the block

Water in a timely manner. This ensures that leaves are not wet for extended periods of time, especially later in the day. Use either overhead watering or sub-irrigation. Use the weight method, described below, to determine when to water.

When to water

Measure the weight of several blocks with transplants when saturated. Monitor the weight on a daily basis and commence watering when the average block weighs 50% less than when saturated. For a 10 x 10 x 7.5 cm block, this is approximately 300–350 g. When watering, ensure the blocks are re-saturated.

Transplants placed directly in the production greenhouse dry out sooner because of the lower relative humidity in the greenhouse (loss of water from the surface of the block as well as due to transpiration). This requires more frequent watering. Night watering may be necessary on cold nights when the humidity in the greenhouse is low.

6. Tomato Crop

Tomatoes are the most widely grown produce in Ontario's greenhouses. Since the early 1990's, nearly all tomato production has been the beefsteak–type tomato, which is a large fruited, red coloured tomato. The optimal fruit size is 200–250 g (28–34 count/ 6.8 kg (15 lb.) box). From the mid 1970's until late 1980's, the pink coloured tomato was widely grown. This tomato was geared for a specific market and had resistance to fusarium crown and root rot disease that afflicted the Ontario greenhouse industry in the 1970's. Consumer demand, as well as the transfer of the disease resistance to the red coloured tomato cultivars, accelerated the change, resulting in little or no pink tomato production in Ontario.

Further change in consumer preferences has seen the increase in cluster tomatoes (tomatoes on the vine — TOV) production. This is a slightly smaller tomato than the beefsteak–type and is harvested on the truss/cluster and marketed as a bunch. As well, Roma–type, cherry, yellow and orange coloured tomatoes are grown for special niche markets.

Two crops of tomatoes are traditionally grown per year. The spring crop is planted in the greenhouse between Christmas and New Year's, with harvest beginning in mid to late March and crop termination in July. A fall crop planted in August follows, harvest begins in October, and the crop is terminated in November or December. Alternatively, a single long–season crop is grown, with planting in mid–December, harvest beginning in mid–to late–March, with the crop finishing in September/October. The single crop system is most common in the Leamington area, while the two–crop system is used throughout the rest of the province.

Operators adjust the start and finish of the crop to suit market demand, as well as available light. The trend to earlier planting continues as design of greenhouse structures and climate controls improve, and early price remains high. Producing marketable tomatoes during the winter months — November, December, January and February — can be carried out using artificial lighting, but requires a strong capital investment, low electrical rates and strong returns at the marketplace to be successful.

A good start by the crop is required to achieve successful tomato production. Healthy transplants with well–balanced growth during the winter months can result in excellent production of high quality fruit. An overly vegetative crop has a large leaf area, delayed flowering, poor fruit set and smaller fruit, delayed harvest and is more prone to diseases. A plant that is too generative has a high fruit load, smaller leaves, a weaker growing point, resulting in poor and delayed fruit set until the fruit load is decreased, and overall lower production.

Cultivar Selection

There are a limited number of tomato cultivars suitable for the Ontario greenhouse industry. The consumer demand for a high quality, large– sized red tomato limits the choice. Some characteristics to keep in mind are the yield, fruit size, growth habit; resistance to russeting (shrink cracking), short calyx, fruit firmness, taste and plant habit. Several new cultivars are available, but require further development in the genetics as well as improved cultural practices. Powdery mildew tolerant cultivars are available and may become more important in the future.

See the OMAFRA Web site at www.gov.on.ca/OMAFRA/ english/crops/hort/vegetable.html#tomatoes or your seed company for more details on tomato cultivars.

Cropping Schedule

There are two common cropping practices in Ontario: a spring–fall crop or long–season crop.

Crop type	Sow	Plant	Harvest	Terminate
Spring–Fall Crop				
spring	mid Nov.	1st wk. Jan.	mid–end March	mid July
fall	late June	1st wk. Aug.	Sept./Oct.	end Nov./mid Dec.
Long–season Crop				
long season	1st wk. Nov.	3rd – 4th wk. Dec.	mid–end March	end Sept./early Oct.

Adjust sowing and planting dates depending upon available light and market commitments. Cropping schedule for a winter crop with artificial lights is as follows:

Sow	Plant	Harvest	Terminate
late June	1st – 2nd wk. Aug.	Sept./Oct.	1st wk. June

Seeding

Sow tomato seed directly into rockwool plugs in styrofoam trays or plastic plug trays. Small operations sow seed by hand while automatic seeders are used in larger operations. Soak plugs with plain water or a complete nutrient solution at EC 0.5 mS/cm prior to sowing. Cover seed with medium grade vermiculite. Place trays in germination chambers maintained at 24 °C –25°C and 100% RH, or on germination benches with under–bench heat and cover with a 2 mil clear polyethylene sheet to maintain temperature and humidity.

Optimum germination temperature for tomatoes is 24°C –25°C. Seed emergence occurs 2 ½ –3 days later. After 60%–70% emergence, remove trays from the germination chamber or the plastic film from the flat on the germination bench. Maintain temperature at 24°C for 1–2 days longer and then gradually lower to 20°C day and night over a 2–day period. After the cotyledonary leaves have expanded, fertilize seedlings with a complete nutrient solution at an EC of 1.0 mS/cm, and gradually increase as the plants develop.

Seedlings benefit from supplementary lighting (18 hr photoperiod at 20 watts/m^2) and CO_2 levels of 800–1000 ppm.

Use a pure source of CO_2 as seedlings are extremely sensitive to by-products of improper combustion of carbon fuels.

Begin transplanting 18–21 days after sowing or when the leaves are touching.

Plant Raising

Transplant seedlings into 7.5 or 10 cm rockwool blocks with preformed holes to accommodate the rockwool plugs. First soak blocks with a complete nutrient solution at a pH of 5.5 and an EC of 1.5–2.0 mS/cm. At each subsequent watering, gradually raise the EC to eventually reach 3.0–3.5 mS/cm. Adjust the EC according to the available light, rate of growth, plant vigour, available moisture and temperature regime followed.

Place seedlings into the hole of the rockwool block either straight or fold by bending the stem 90° or 180°. By bending the seedling, the cotyledonary leaves and the growing point are placed closer to the surface of the rockwool block. This allows for root development along the buried stem providing greater plant stability.

If seedlings are placed straight up in the hole, they must be staked. Stake with a thin bamboo stick, close to the seedling. Use elastic bands or metal rings to hold the plants to the stake. Cover hole with a layer of medium grade vermiculite for added stability.

Staked plants are allowed to grow bigger as the stake provides support to the plants. This delays the need to tie the plants up to the overhead wires. There is also less damage to plants when transporting at transplanting time.

Maintain greenhouse temperature at 23 °C–25°C for 1–2 days after seedling transplanting to hasten root establishment. Following this, gradually lower the temperature to 19°C (day and night) at a rate of 1°C/day. Supplementary light (18 hr photoperiod at 20 watts/m^2) and CO_2 levels of 800–1000 ppm benefit the crop by producing stronger rooted transplants that are compact with sturdier stem and earlier flowering.

Transplants are ready to plant in the production house when the first flower clusters are well established and/or the first flower begins to open, about 6–7 weeks after sowing. During the early stages of tomato plant growth, the plant tends to be strongly vegetative. It is important to provide the proper cultural conditions to induce the plant to a more generative (flower production) growth phase immediately to ensure early, high quality production. By altering temperature, relative humidity, water and fertility in relation to the available light, this control of the plant can be easily achieved. [*Plate 7* and *Plate 8*]

A well–established first flower cluster decreases the possibility of the plant being too vegetative after transplanting in production greenhouses. If transplanting occurs too early or the plant growth is not controlled, the plant remains too vegetative. This results in delayed flowering and first harvest, a tendency for smaller, misshapen fruit and a plant more prone to disease infestation. On the other hand, a plant that is too generative results in strong flower production, a weak top, slower growth and delayed harvest. The objective at this stage is to strike a balance between generative and vegetative growth.

Plant Spacing

In general, a plant spacing of 0.37–0.41 m^2 (4.0–4.9 ft^2. per plant) or 2.4–2.7 plants/m^2 is ideal. Arrange plants in a twin–growing row 0.6–0.8 m apart, with a 0.9–1.2 m walkway separating the twin growing rows. Plant spacing within the row is adjusted to achieve the desired plant density. In rockwool culture, use 2 plants/90 cm slab with the bags spaced within the row.

When light levels are higher later in the season, plant density may be increased to 2.9 stems/m^2 by allowing a side shoot to develop into a productive stem on every 5th plant. However, care must be taken as this tends to alter the plant:rockwool volume:water interaction, resulting in smaller sized fruit, and increased disease incidence, especially when light levels are poor. Developing and training an extra side shoot to increase the stem density is normally initiated in March and works best in a "V" system.

Pruning and Training

Prune greenhouse tomatoes to a single stem. Remove all side shoots or suckers at least once a week. Support the plants with polypropylene twine. Tie one end of the twine loosely to the base of the plant with a small, non–slip loop and attach the other end to an overhead supported wire 1.8–2.5 m above the plant row.

In newer greenhouses equipped with hot water pipe rail systems and scissors carts, overhead wires are 3.0–3.5 m high. Proper tying of the twine at the base of the plant is important as too tight a knot may choke the plant or, if too loose, the plant falls and snaps the stem.

In some cases, the twine can be placed between the bottom of the transplant block and the top of the rockwool slab, so the weight of the plant keeps the twine in place. Loop the twine around the plant as described above. However, problems can develop, with wicking of the nutrient solution up the twine. This damages the plant where the twine and stem are in contact, resulting in a loss of production. These are potential sites for diseases such as botrytis to occur.

As the plant grows, twist the plant around the twine in one or two easy revolutions for each fruit cluster. Once the plants are larger and heavier (usually 4th – 5th cluster), use plastic snap–on clips to attach the plants to the twine. For the spring crop, drape an additional 2.0–2.5 m of twine over the top wire. As the plant reaches the wire, untie the twine and lower regularly, allowing the lower section of the plant to lie on the ground or on wire supports. Overhead hooks, with a season's supply of twine stored on them, are also available and are commonly used in high–wire tomato production houses. These increase the ease of lowering of the crop when layering.

The lower leaves of the tomato plant are removed to:

- improve bottom air circulation
- maintain ideal environment at the base after the plant is lowered
- allow workers to find the fruit easily when harvesting.

Usually, remove only 1–2 leaves at a time, as too many leaves removed all at once alters the leaf:fruit ratio and adversely affects yield. In general, a maximum of 1.2 m (20–22 leaves) of leaf bearing stem is recommended at all times. In some cases, only 12–15 leaves are recommended to maintain fruit quality.

Pinch off or top the growing point of the plant about 6–8 weeks before harvest is to be discontinued. This transfers the sugars and energy normally used to produce new flowers and leaves to other components of the plant, namely the fruit, causing them to enlarge and ripen early.

Cluster Pruning

As most modern tomato cultivars set fruit readily, all flowers on a truss may set fruit. The time–frame between setting of the first flower and the last may be 4–10 days, resulting in fruit size gradient reflected at harvest time. To ensure uniform size and rapid harvest, prune each cluster to 4 fruit. Prune once the first 4 flowers are properly set, by pinching off the remainder of the flower truss. Under good light conditions, with a strong vigorous variety or a fall crop, it may be necessary to leave 5 fruits/cluster up to the 3rd cluster after which 4 fruits/cluster are left. Adjust the number of fruit/cluster and the number of clusters at 5 fruits/cluster depending on available light and plant vigour. This decision must be carefully considered as too much fruit load on the lower clusters severely restricts later production. Truss supports may be necessary to prevent the fruit truss from kinking. [*Plate 9* and *Plate 10*]

Pollination

Pollination is necessary for normal fruit set to occur. Pollen from the anthers must reach the ovaries at the base of the flower for fertilization and fruit development to occur. The number of seed developed (number of pollen grains joining the ovaries) determines fruit size, quality and shape. Tomato flowers are self–pollinating, but to ensure high quality, uniform tomatoes, electric bees or buzzers, or bumblebees are used to increase pollination. [*Plate 11*]

Successful pollination involves:

- production of viable pollen
- release of the pollen from the anthers to the stigma
- germination of the pollen grains on the stigma
- growth of the pollen tubes down the stigma resulting in fertilization (fruit set)

Adverse temperatures, light and nutritional conditions cause some, if not all, of these processes to fail, resulting in poor fruit set and poor fruit quality. Day temperature should not fall below 18°C or exceed 30°C once flowering starts.

Bumblebees

Bumblebees are commonly used today to pollinate tomato crops for the production of high quality fruit. Introduce bumblebee hives (2–3 hives/ha) into a tomato greenhouse once the first cluster is fully opened. When bumblebee workers visit the flowers to obtain pollen, many pollen grains are disturbed from the stamens landing on the stigma, initiating pollination. The bumblebees visit flowers when pollen is available (mid morning to early afternoon), and visit the same flower several times over the bloom period.

As the plant grows and more flowers open, add extra hives (4–5 hives/ha as determined by the bumblebee supplier). As the hive ages, the worker bumblebee population declines, and the social order of the hive changes, resulting in an inefficient hive. Hives lose their pollination efficiency after 6–8 weeks. At this time, replace the hives or bring more hives in to maintain good pollination. This is repeated throughout the growing season.

A brown discoloration or marking of the cone/trumpet of the flower indicates if a bumblebee has visited the flower. Monitoring these marks determines whether the bumblebees are performing well [*Plate 12*]

Place hives in a convenient location on a sturdy stand or shelf — 1.0–1.5 m high in a shaded area or provide a shade cover provided to prevent overheating in the summer months. The hives must be located away from vibration or drafts to ensure proper functioning. Hives placed in a cool location are slower to develop adequate adult worker bumblebees to efficiently pollinate the crop.

Modern hives are designed to provide a carbohydrate source for the bumblebees, requiring little or no maintenance by the operator. The hives are also equipped with a one-way opening that, when in operation, only allows the bumblebees to enter the hive, and not exit. This is necessary to capture all the bumblebees when the hives are being removed if and when chemical sprays are applied to the tomato crop. Bumblebees are sensitive to various chemicals. Once chemicals are introduced into the hives, or brood, they cause the hive to deteriorate, resulting in poor pollination. Thus, a good biological control program against pests is necessary to obtain full benefit of bumblebee pollination.

While bumblebees will exit greenhouses through vents, they usually return. However, if the outside temperature is low, or the vents close before the bumblebees return, these bumblebees will die, especially in February and March. This can be a problem in gutter vented double poly greenhouses, where the light quality through the vent opening appears different from that through the double poly — attracting the bees outside. Under cool temperatures, the bumblebees die resulting in a decrease in hive size and pollination activity. This can be rectified by:

- changing the poly covering to one that has smaller light transmission difference
- decreasing vent opening by installing end wall fans to assist in early venting
- installing bee screens at the gutter vent to prevent escapes.

In small tomato greenhouses, bumblebee pollination may not be effective. The number of bumblebees in an average mature hive can be as high as 300 adult bees. When the demand for pollen is very high, excessive visits to each flower can cause damage to the flower and in extreme cases flower abortion. Thus, hand pollination with the use of electric bees must be conducted.

During late fall, winter and early spring, flowers of most cultivars grow with a slightly different shape, and natural pollination becomes more difficult. This is a result of low light and temperature, and is occasionally aggravated by high nitrogen. The optimum time for pollination is between 11:00 a.m. and 3:00 p.m. when flowers are dry and pollen is shedding. Other methods, such as tapping the overhead wires or the string supporting the plants, and coarse water sprays have not generally been satisfactory. Backpack air blowers similar to leaf blowers can also be used to pollinate the flowers. Fruit quality problems related to inadequate pollination are invariably the result of poor and uneven seed set which causes hollow misshapen fruit.

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Climate

Air temperature has a profound effect on growth and flower development, fruit setting, development, ripening and quality. The 24 hr average temperature affects the speed or rate of growth. The higher the 24 hr average temperature, the faster the growth. A tomato crop achieves its maximum growth at 25°C day and night temperature, but maximum fruit production is achieved at 18°C night and 20°C day or a 24 hr average of 19°C. The day night temperature differential determines the morphology of the plant (i.e., its shape) and the degree of vegetativeness or fruitfulness.

Adjust temperatures based on available light to maintain high rate of growth, with large fruit of high quality. Under lower light conditions (early winter or cloudy days) maintain a lower 24 hr average temperature that is then increased when the light level increases. Adjust the day–night temperature difference to maintain plant vigor, and fruit size. A large day–night temperature differential shifts the plant to a more generative phase (more flowers, thinner head, and larger fruit size) while a low or no temperature differential results in a more vegetative plant (less flowers, thicker head).

TABLE 6–1. Recommended Air Temperatures (°C) for Tomatoes

	Low Light	High Light	With CO_2
night minimum	17	18	18
day minimum	19	21	21
ventilation	21	24	26

Note 1: During very bright weather, temperatures higher than 26°C will not harm the plants, but above 29°C the blossoms will be injured on most cultivars.

Note 2: A minimum media temperature of 16°C is recommended (optimum 18–21°C).

Light is also a critical component of tomato production during the winter months. Under low light conditions in winter, the plant tends to have long internodes, reduced flower bud development and clusters that fail to set fruit. These problems are minimized by decreasing the rate of growth through a combination of one of the following production practices:

- by lowering 24 hr average temperature
- lowering the volume of water applied
- raising EC of the nutrient solution and the root zone media
- and lowering the RH (higher VPD).

Whitewash applied to the exterior greenhouse covering reduces both the light intensity and temperature during the summer inside the greenhouse. This enhances a stronger head, improves flower quality and fruit set, as well as decreases fruit quality problems associated with high surface temperatures of the fruit.

The tomato crop can withstand a wide range of relative humidity as long as the RH does not fluctuate drastically over a short period. At low RH (high VPD), water supply to the crop is critical; while at high RH (low VPD) incidence of diseases can increase. High relative humidity (low VPD) during the day can improve fruit setting. Too low an RH (a high VPD) results in poor pollination and fruit set. Ideally keep a relative humidity of 75%–85% or a VPD of 0.4–0.8 kPa.

To alter plant vigor or appearance, change the RH or VPD. For example, under low RH or high VPD, the plant tends to have a thinner head and leaves. At higher RH or low VPD, the plant tends to have thicker leaves and heads, flowers with extended trusses or stems that are more prone to kinking or bending, resulting in poor fruit quality (size and shape).

Carbon dioxide supplementation benefits the tomato crop at all stages during the winter (no ventilation). During sunny days, apply a minimum CO_2 concentration of 1000 ppm, and 400 ppm CO_2 when vents are opened more than 10%. Under low light conditions (40 watts/m^2), 400 ppm is ideal. In summer (with ventilation) it is economical and has become popular to apply supplemental CO_2 at a concentration of up to 400 ppm (especially early in the day and late evening before sunset).

Horizontal airflow (HAF) fans help minimize temperature gradients in the greenhouse, and uniformly distribute CO_2 throughout the canopy. An air speed of 1 m/second is recommended. HAF fans must be turned off during the dehumidification cycle to efficiently dehumidify the greenhouse. The conventional currents created by the heating system are disrupted by the horizontal airflow, preventing the warm, moist air from easily escaping through the vents. Table 6-2, page 51, is a summary of growing recommendations for tomatoes.

Nutritional Requirements

Sustained fruit production is accomplished only under optimum environmental conditions and by timely applications of water and nutrients. A well–balanced plant is judged by its thick stem, dark green leaves and its closely spaced, large, readily–setting flower clusters. A properly nourished plant should have a 1 cm thick stem at a point 15 cm below the growing tip. Thicker stems indicate excessive vegetative growth and are usually associated with poor fruit set and low productivity. Thinner stems usually indicate carbohydrate starvation, slow growth and ultimately low overall productivity.

A mature tomato crop uses 2–3 L of water per plant per day when light levels are high (average summer day). A complete nutrient solution must be applied at all times to sustain the growth and fruit development necessary to obtain high production of good quality tomatoes. The fertilizer schedule, Table 6-3, on page 51, is adjusted based upon the stage of the crop.

Tomato plants have different absorption rates (especially nitrogen and potassium) at various stages of growth. The nitrogen absorption by the tomato plant during the first 2–3 flower trusses is about the same as potassium. But as the fruit load increases so does the potassium uptake, resulting in 2:1 potassium:nitrogen uptake. An excessive amount of nitrogen under low light conditions early in the production cycle results in an overly vegetative plant prone to disease, poor flower development, fruit set and size. Lower nitrogen feed during this phase helps control plant growth. (Note: other factors can also strongly influence plant growth and must be considered at the same time.)

The volume and timing of the nutrient solution applied through fertigation is critical in rockwool culture, and greatly affects fruit quality. Begin fertigation 1–2 hr after sunrise and end 1–2 hr before sunset. This helps decrease incidence of 2 physiological disorders, russetting and fruit cracking in the summer, as well as diseases. Night watering may be needed during the winter months when heating systems are fully operational and the RH in the greenhouse is low, or during the summer when light intensity and temperatures during the day in the greenhouse are high.

Fertilizer application is very critical and greatly influences the growth and development of the crop, and subsequently the quantity and quality of the fruit. The average uptake of the major nutrients by a tomato crop is estimated as follows:

nitrogen	370 kg/ha
phosphorus	50 kg/ha
potassium	680 kg/ha
magnesium	290 kg/ha
calcium	45 kg/ha

Regulating the supply of water and nitrogen is the most common and effective technique used to control crop growth. Infrequent irrigation and low volume, low relative humidity and high EC in the irrigation water result in hard plants and slower growth. Regulation of EC is the preferred method of slowing growth because it is simple, effective and dependable. Nitrogen (N) supply can also be regulated directly by adjusting the N fertilization, or indirectly by varying the supply of other nutrients, such as potassium (K). A high K:N ratio in the fertilizer solution is a frequently used technique to slow down growth.

Nitrogen (N)

This nutrient has the greatest impact on vegetative growth. High rates of N induce vigorous vegetative growth to the detriment of fruit production. However, under hot and bright conditions, the N level must be increased to enable the plant to continue growing and to maximize its fruit production potential.

Strong thick stems, curled leaves in the head of the plant, big flower trusses and individual flowers, mark an excess of N with poor fruit set. Symptoms of N deficiency are hard plants with thin heads, light green foliage and pale yellow flowers.

Potassium (K)

Potassium has a great influence on fruit quality and at high rates is also effective in hardening growth. Potassium levels are particularly critical at planting time for subsequent growth control and preventing ripening disorders. The ratio between potassium and nitrogen is also important in growth control. The higher the ratio, the slower the growth. Fruit quality problems such as blotchy ripening, boxy fruit and green–back (to some extent) are associated with low levels of K.

Phosphorus (P)

Phosphorus is used in much smaller quantities than N and K. Initially, phosphorus is important for early root growth, and is strongly influenced by the temperature and the pH of the growing media. At low temperatures P uptake decreases and at high pH, it is not readily available for plant uptake. It has a profound effect on both vegetative growth and fruit set. Deficiency symptoms include a characteristic purple colour of the leaf veins and the stem, thin growth, and poor cluster development. Phosphorus toxicity is uncommon.

Magnesium (Mg)

Although magnesium deficiency is very common, it rarely results in yield reduction (it may affect fruit quality). Deficiency usually exists only in the plant and is related to high K feeds or poor root development, both of which make it difficult for the plant to take up sufficient magnesium. The plant is then forced to move magnesium from the old to the new leaves. A magnesium deficiency (chlorotic older leaves) is easily corrected with Epsom salt sprays.

Calcium (Ca)

Calcium deficiency usually causes blossom end rot of the fruit and dieback of the growing tips. In most cases, Ca deficiency is caused by water stress because of inadequate or uneven watering, frequent and large variations in relative humidity, imbalanced fertilizer program or high salts. Sprays of calcium nitrate or calcium chloride help correct a Ca deficiency, but improving water balance in the plant is a more practical solution to the problem.

Sulfur (S)

Sulfur is rarely a problem since it is present in many fertilizers as a carrying element. However, high sulfur levels can become a source of excessively high salts and can also adversely affect the uptake of molybdenum.

Iron (Fe)

Iron deficiency, a frequent problem, is usually observed as chlorosis of young leaves. In most cases, iron deficiencies are induced. The indirect causes of iron deficiency can be high media pH, too high a manganese level, poor root growth or anaerobic conditions due to over watering. Foliar sprays of iron salts or iron chelates are helpful, but the best solution is to eliminate the source of the problem.

Manganese (Mn)

Manganese deficiency is frequently confused with iron deficiency. Symptoms are interveinal chlorosis that becomes more yellow as the deficiency progresses and light green coloured veins. As the deficiency symptoms become more severe, brown spots appear at the base of the leaflets. However, in most instances, it is an expression of iron toxicity. Manganese toxicity can be a problem and is encountered when media, especially soil, is excessively steamed and not followed by leaching.

Copper (Cu)

Copper may occasionally be deficient in peat media or in soilless culture if it is omitted in the fertilizer schedule. Symptoms are similar to high salts, with dark green younger leaves that frequently wilt. As symptoms progress, the leaflet tips become necrotic and flower buds fail to develop.

Boron (B)

Boron deficiency symptoms include brittleness of leaves, premature wilting, and in severe incidences, dieback of the growing tips. This deficiency is easily corrected with foliar sprays of a borax solution. The rate of application is important since boron toxicity can cause severe plant damage.

Zinc (Zn)

This element is rarely deficient. Toxicity is a potential problem in recirculating hydroponic systems when galvanized piping is used. The nutrient solution reacts with the piping, releasing excessive quantities of Zn. Also, rainwater collected from newly erected greenhouses where the galvanized gutters have had no special treatments can cause Zn problems.

Molybdenum (Mo)

Low pH conditions, or high sulfur levels can induce molybdenum deficiency. Although symptoms of molybdenum deficiency are not easily identifiable, leaf tissue analysis is a dependable diagnostic tool.

Harvesting and Storage

Harvest greenhouse tomato fruit with the calyx attached to the fruit to help identify the product. Harvest 3 times a week or every other day, especially during the summer. This ensures all fruit is harvested at about the same stage of ripeness. Harvest fruit when they are turning from green to orange–red in colour. Some growers may harvest at the breaker stage (blossom end of the fruit starting to show colour). Tomato fruit harvested at a more advanced stage of ripening has greater flavour, but may not have as long a shelf life as it becomes over–ripe more quickly.

Harvest manually by snapping or breaking the calyx at the knuckle (a natural break point on the flower stem). Place fruit in picking baskets or crates to prevent punctures by the calyx. Clip the stem if necessary to minimize fruit punctures when handled during packing and at display counters. Fruit that is dropped will easily bruise, resulting in decreased shelf life.

Pick tomatoes as early as possible in the morning while it is still cool. Move fruit quickly to a covered area or directly to a cooler. Fruit left in the greenhouse rapidly overheats and deteriorates. Ideally, cool fruit to 12°C (53°F) as quickly as possible. The packing facilities must be cooled (15°C) to maintain fruit quality and, if required, store fruit at 12°C after grading and packing before shipping in cooled trucks to the marketplace. Computerized, colour sorters with weight and size grading packing lines are commonly used to pack the tomatoes. Pack uniformity (colour, size, and quality) is critical to ensure good acceptance at the marketplace. Label all tomato fruit with a PLU or bar coding sticker during packing.

After removing the fruit from cold storage, take care to avoid condensation on the fruit, by either moving it into a dry atmosphere or by raising the fruit temperature gradually.

Contact the Ontario Greenhouse Vegetable Growers, Box 417, Leamington, Ontario N8H 3W5, telephone: (519) 326–2604 for updated fruit grade specifications and price structuring according to fruit grade.

TABLE 6–2. TOMATO: Summary of Growing Recommendations

	Germination	Plant Raising	Transplanting	Harvesting Stage	Full Harvest
Temperature					
day °C	25°C	19°C–21°C	24°C	19°C	20°C–22°C
night °C	25°C	19°C–21°C	24°C	19°C	17°C–19°C
EC (mS/cm)	0.0–1.0	2.5–3.0	2.5–3.0	2.7–3.5	2.7–4.0
pH	5.8	5.8	5.8	5.8	5.8
Vol. of feed (L/day)*		0.2–0.3	0.2–0.3	0.5–1.5	1.5–2.5
Fertilizer Schedule		A	B	C	D

* as required (watering strategies)

TABLE 6–3. Fertigation Schedule for Tomato (ppm nutrient)

	N	NH_4	P	K	Ca	Mg	Fe	Mn	Zn	B	Cu	Mo	S	Cl	HCO_3
A. Slab Saturation	200	10	50	353	247	75	0.8	0.55	0.33	0.5	0.05	0.05	120	18	25
B. For 4–6 wks after planting	180	10	50	400	190	75	0.8	0.55	0.33	0.5	0.05	0.05	120	18	25
C. Normal Feed	190	22	50	400	190	65	0.8	0.55	0.33	0.5	0.05	0.05	120	18	25
D. Heavy Fruit Load	210	22	50	420	190	75	0.8	0.55	0.33	0.5	0.05	0.05	120	18	25

	Kg/1000 L (Dilute 1:100)			
Fertilizer	A	B	C	D
Calcium Nitrate	112	82.1	82.1	82.1
Potassium Nitrate	25.72	42.4	40.89	56.27
Monopotassium phosphate	6.75	6.75	6.75	6.75
Potassium Sulphate	45.11	38.08	39.21	31.81
Potassium Chloride	3.75	3.75	3.75	3.75
Magnesium Sulphate	66	66	56	66
Ammonium Nitrate	0	4	8	8
	g/1000 L (Dilute 1:100)			
Iron Chelate 13%	615.38	615.38	615.38	615.38
Manganese Sulphate	207.69	207.69	207.69	207.69
Zinc Sulphate	94.29	94.29	94.29	94.29
Borax	326.67	326.67	326.67	326.67
Copper Sulphate	16	16	16	16
Sodium Molybdate	10.87	10.87	10.87	10.87
Desired EC (mS/cm)	2.5–3.0	3.5	3.0–4.0	2.5–3.5
Desired pH	5.8	5.8	5.8	5.8
Vol of Water (L)*	0.25–0.50	0.5–1.0	1.0–2.0	1.5–2.5

(*as required (watering strategies)

Use this table as a guideline only. Fertilizer schedules must be tailored to the individual operation and will depend upon factors such as: source of water, culitvar grown, time of year, etc.

7. Cucumber Crop

The success of cucumber production in the greenhouse depends upon one's ability to maintain ideal conditions for growth. Cucumber plants are extremely sensitive to change. Optimizing the greenhouse environment including light, temperature, humidity, air movement and the root environment (i.e., root temperature, moisture availability, nutrition, etc.) produces high yield and quality. A tropical plant originating from the Indian subcontinent, the cucumber plant performs best when grown under high light, temperature, humidity, moisture and fertility conditions.

English cucumber is the only commercial cucumber grown in the greenhouse. These seedless cucumbers are parthenocarpic, with flowers that do not require pollination for fruit formation.

Cucumber plants grow rapidly, and depending on light and growing conditions, produce marketable fruit in 8–12 weeks. In general, 2 crops of cucumbers are grown per year: first a January planting with mid-February harvest and termination in mid-July or August, followed by an August planting, end of September harvest and termination end of November/beginning of December.

A 3-crop production cycle to maintain high fruit quality and market share consists of a December planting with late-January to early-February harvest and termination in May, followed immediately with a 2nd planting that terminates in August. The 3rd planting, started immediately after clean-up, is terminated in December.

The planting and termination dates are adjusted based on the marketing schedule and light availability. In the past, producing cucumbers during November, December and January has been successful when prices have been traditionally higher. However, recent increases in imported seedless cucumbers has dropped the price, lowering returns. Given the high cost of fixtures and electricity, supplementary light is not financially worthwhile.

Cultivars

There is a wide selection of cultivars suitable for Ontario greenhouse growing conditions. Fruit quality, yield and plant habit vary between cultivars, and seed companies. With the marketplace demanding fruit 32–42 cm long and a diameter of 4 cm, a suitable cultivar should provide a higher percentage of medium-large fruit. There are lower returns on short cucumbers.

The use of the PMT (Powdery Mildew Tolerant) cultivars is increasing, and each seed company has a selection that may be suitable to the Ontario grower. PMT or resistant cultivars have a slightly lower yield, making it more difficult to grow them economically. Earlier PMT cultivars produced shorter cucumbers, but the new cultivars are longer. There are also some operations that are growing the mini-cucumbers or gherkin-type cucumbers for specific markets.

See the OMAFRA Web site or your seed supplier for more details on the individual cultivars.

Seeding

Seed may be sown directly into rockwool blocks or in flats filled with vermiculite. After emergence, transplant the seedlings from the vermiculite flats into rockwool blocks. Cucumber seed germination is rapid, and must be treated accordingly. The optimum seed germination temperature for cucumbers is 26°C–28°C.

Cucumber seedlings emerge 2–3 days after sowing and if sown in flats are ready for transplanting into blocks in 4–6 days.

Plant Raising

After transplanting, maintain a temperature of 25°C day/night to rapidly establish roots. Subsequently, lower the temperature to 23°C day and 21°C night, with the day temperature based on light intensity. At higher light intensities, a 2°C increase is beneficial. To avoid impeding root development, it is very important to maintain the block temperature between 21°C–23°C. A too wet or too dry a rockwool block also impedes root development.

To maximize space efficiency, initially place the blocks close together; increase the spacing when the leaves begin to touch. This increases light interception and helps maintain a sturdy, stocky plant. Supplementary lighting with HPS lamps at 20 watts/m^2 for 24 hr improves plant quality and reduces the time required to produce a plant suitable for transplanting. Supplemental CO_2 (1000 ppm on sunny days, 400 ppm on cloudy days or when supplementary lights are used) helps achieve the desired plant in a shorter time.

A cucumber plant is ready for transplanting into the production houses when:

- 4–5 leaves have developed,
- is about 25–30 cm tall and
- weighs about 25–40 g.

To obtain a plant of this size, it must be staked. Place a stake in the pot beside the plant. Use elastic bands or metal rings to hold the plants to the stake. At transplanting time, the staked plants will be less prone to damage during transport, and will be easier to string up after planting in the greenhouse.

Plants can be moved into the production greenhouses earlier (3–4 leaf stage). Place the plants beside the opening in the rockwool bag and water the plants with the drip irrigation system. The advantage of moving the plants earlier include:

- decreasing the time required in the starter house
- allowing the use of smaller starter houses.

However, the younger plants placed directly in the greenhouse require greater care to ensure proper root zone temperature and adequate moisture. Once they reach an adequate size, they may be moved onto the opening, allowing roots to develop into the slab.

Plant Spacing

In general, space plants at 0.55–0.74 m^2/plant (6–8 sq.ft./plant) or 1.4–1.8 plants/m^2. The larger spacing per plant:

- improves fruit quality, length, colour
- decreases costs, number of seeds, blocks, growing media, labour
- maintains a high yield (number of cucumbers/plant or cucumbers/m^2).

In general, cucumber plants are grown in twin growing rows with a walkway between each row. The heating pipes are located on the walkway for a hot water heating system and within the twin rows for a steam heating system. The walkways are 140–170 cm wide and the space between the twin rows 100–120 cm. Plant spacing along the growing row varies, depending on the growing system used to achieve the plant population desired.

Growing Media

Rockwool is the media most commonly used in Ontario for cucumber production. A cucumber slab measures 20 cm wide x 7.5 cm high x 90–100 cm long. With a 90 cm long slab, use 2 plants/slab; with a 100 cm long slab use 3 plants/slab. Space the slabs within the rows to provide the desired plant density. Using 3 plants/bag requires less rockwool.

To spend even less on rockwool, consider using the V–system to grow plants. Use a single growing row where the plants from the single row are trained to form 2 rows of stems at the appropriate stem spacing (1.35–1.81 stems/m^2). This system lends itself well to recirculating the nutrient solution.

After placing the rockwool slabs, soak the bags at an EC of 2.0–2.5 mS/cm and a pH of 5.5 (see Section 4, *Growing Media*, page 31) Immediately after planting, irrigate the crop with a complete nutrient solution (EC 2.0 mS/cm and a pH of 5.5) of sufficient volume to fully saturate the slabs. Cut the bags to allow the excess solution to drain (completed after planting). Depending on light conditions, do not water for 2–3 days; then water according to plant requirements. Use a nutrient solution containing a higher calcium level from planting out until plants reach the wire (see

Table 7-4, *Summary of Fertilizer Schedule for Cucumbers*, page 56.)

Crop Training

The modified umbrella system is commonly used in Ontario. Plants are trained along a twine attached at the base of the plant and the overhead wire (1.9–2.0 m high). Once the plants reach the wire, there are 2 options.

1. Remove the growing point of the plant, allowing 1 leaf to remain over the wire. Develop two laterals 1–2 nodes below the wire. Attach them to the overhead wire via special hooks or by wrapping around the wire. After the laterals with about 3–4 nodes are trained along the wire, let them grow down; remove the growing point when the lateral is approximately halfway to the ground. Then, allow another lateral at the wire to develop and train in a similar fashion. After harvesting all the fruit from the first lateral, remove to make room for the next lateral to develop. Repeat this process throughout the growing season. [See Figure 7-1, *Cucumber Pruning System 1*, page 55]

OR

2. Train the main stem along the wire until it reaches the neighbouring plant when the growing point is pinched off. At the 2nd and 4th node from the bend, allow the laterals to develop. Have these laterals hang down; pinch off when they are half way to the ground. Then develop the next set of laterals to develop off the main stem along the wire. Repeat this process throughout the growing season. [See Figure 7-2, *Cucumber Pruning System 2*, page 55]

Once the basic framework is achieved, subsequent pruning depends upon the vigour of the plants. For good fruit colour, make sure there is good light penetration. To achieve this, it may be necessary to:

- remove 1 or 2 healthy green leaves in a vegetative crop
- train laterals to grow downwards.

During the season remove the senescing (aging or drying out) leaves above the wire. Train a lateral over and along the wire so that it receives good light. Fruit development and further lateral growth from this overhead lateral will continue to produce fruit during the remainder of the season.

Fruit Pruning

Fruit pruning is necessary to ensure a proper balance between the number of leaves produced, and the number of developing fruit. If the plant is too vegetative (i.e., too many leaves), fruit set and harvest is delayed. If the plant is too fruitful, future cucumber production is jeopardized. A balanced plant maintains a steady production throughout the season, minimizing weekly periods of high production followed by low production the following week. In a fruitful crop, where there is too much fruit in relation to leaf area, young fruit take longer to mature, become crooked or abort. This restricts new flower development and growth. Use Table 7-1, *Fruit Load on Young Cucumber Plants*, as a guide to balance the young cucumber plant.

TABLE 7–1. Fruit Load on Young Cucumber Plants

	Ht of plant, or # leaves before 1st fruit	# fruit to wire (2 m)
Winter planting (Dec., Jan., Feb.)	90–100 cm OR 10–12 leaves	3–4
Spring/fall planting (Apr., May, June)	80–90 cm OR 8–10 leaves	5–8
Late fall (Oct., Nov.)	90–100 cm OR 10–12 leaves	3–4

On the main stem, only allow 1 fruit per alternate node to develop at all times. On the laterals, allow 1 fruit per node to develop.

Climate

Temperature strongly influences the rate of development, fruit length, colour and the balance between vegetative growth and fruit development (generative growth) of seedless cucumbers. Adjusting the 24 hr average temperature determines the rate of growth or speed of growth. The optimum 24 hr temperature for cucumbers is 21°C. Varying the day and night temperature influences the plant morphology and alters the vegetative: generative balance, that is leaves:fruit balance. [See Section 2, page 17]

In general, use an initial high 24 hr average temperature (day and night temperatures close together) to rapidly establish the plant and reach the overhead wire. This creates plants with thinner stems, longer internodes, and widely spaced, slightly thinner and smaller leaves. Subsequently, lower the night temperature to encourage development of thicker laterals and strong flowers. Plant appearance determines the level and duration of the temperature drop. Use a lower temperature for a longer time to thicken the growing stem and leaves; and a higher temperature to thin it. [See Table 7-2, *Temperature Regime for Cucumber Production*, page 57]

To minimize water condensation on the fruit, gradually raise the air temperature at the end of the night . Raise the temperature 1°C/hr, with the day set temperature achieved at least ½ hr before sunrise. Sharp changes in temperature results in sharp changes in relative humidity (RH) or vapour pressure deficit (VPD).

Do not try to quickly lower the temperature or relative humidity with a sharp increase in venting. The fruit may suffer from chilling injury, curl or abort. A VPD between 0.4–0.8 kPa minimizes the chance of condensation, and maintains an actively transpiring plant.

Cucumber plants grow rapidly and may use up to 3-4 L of water per plant per day, especially a mature, fruit bearing plant in the summer. Apply a complete nutrient solution at all times. In rockwool culture, there may be as many as 30 irrigation cycles in a day. See Table 7-4 for a suggested fertilizer schedule for greenhouse cucumber production.

FIGURE 7-1. Cucumber Pruning System 1

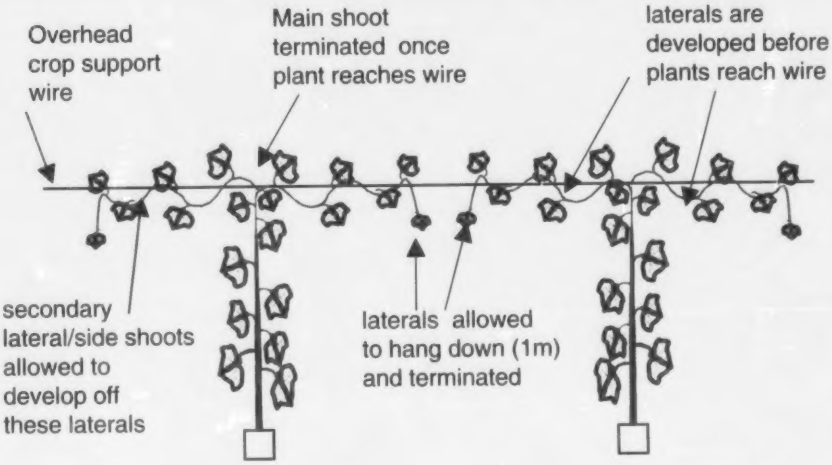
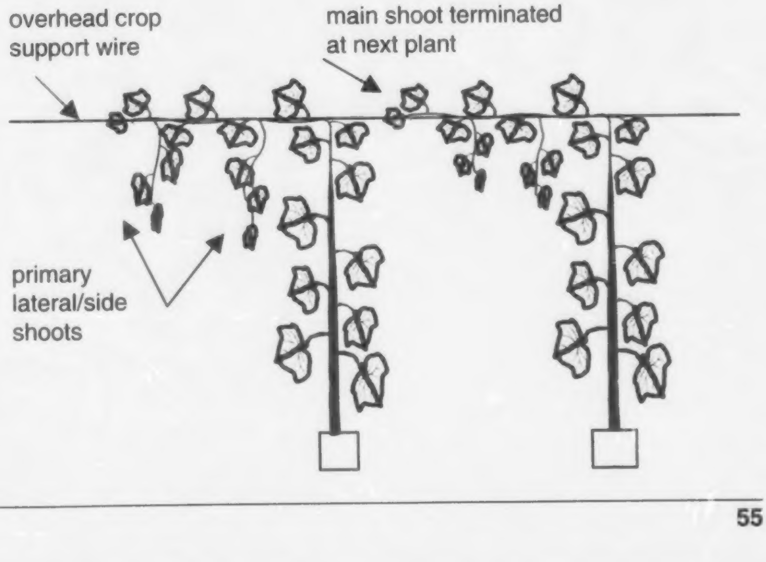

Overhead crop support wire
Main shoot terminated once plant reaches wire
laterals are developed before plants reach wire
secondary lateral/side shoots allowed to develop off these laterals
laterals allowed to hang down (1m) and terminated

FIGURE 7-2. Cucumber Pruning System 2


overhead crop support wire
main shoot terminated at next plant
primary lateral/side shoots

The concentration of fertilizer applied (EC) and the amount of water applied varies with:

- the time of the year
- size of the plant
- prevailing greenhouse environmental conditions.

Applying a higher EC solution increases fruit quality and shelf-life. Avoid excessive application of the nutrient solution to the root zone because saturation of the media increases the incidences of Pythium root rots. Start watering 1–2 hours after sunrise and terminate 1–2 hours before sunset. This allows the aeration of the root zone to occur during the night. Night watering may be necessary on cold winter nights when the demand for heat is high and the greenhouse RH is low, or on extremely sunny, dry days in the spring and summer. Over watering of a crop produces soft stem growth prone to diseases such as *Botrytis*, gummy stem blight, or *Penicillium*. See Table 7-3, page 56, for a summary of growing recommendations.

TABLE 7–2. Temperature Regime for Cucumber Production

	Day	Night	Vent
After Transplanting (3-4 days)	25°C	25°C	None
Growth to wire (3 wks)	23–25°C	23°C	+2°C
Until first lateral harvested/picked	23°C	21 °C	+2 °C
Remainder of season*	23 °C	17–21°C	+2 °C

* This variation in night temperature is suggested to alter plant growth. The warmer night will result in thinner plants, rapid fruit development; the cooler night will result in a thicker plant, strong lateral growth and flower development, and slower plant growth.

Harvesting and Storage

Cucumber fruit matures from flower to harvesting size in 10–14 days, depending on factors such as cultivar, light, temperature, moisture and nutrition.

Minimum marketable length is 28 cm with a 4 cm minimum diameter. Cut, not twist, fruit from the plant. A clean cut of the fruit stalk allows for rapid healing of the wound, and decreases the chance of disease infection.

To prevent fruit from becoming over-mature, harvest cucumbers every other day. Daily harvest may be necessary in some weeks in the summer when fruit growth is rapid. Traditionally, cucumbers are harvested 3 times per week.

Seedless cucumbers have a skin that provides little resistance to desiccation. They lose water very rapidly. Shrink-wrapping the fruit extends the shelf-life and allows attaching of PLU or bar coding labels. Contact the Ontario Greenhouse Vegetable Growers (OGVG) regarding grade specifications and label requirements.

Store cucumbers at 13°C away from drafts. The fruit is extremely sensitive to ethylene -- 0.5 ppm of ethylene causes cucumbers to yellow. Do not place cucumbers in storage facilities or transport with ethylene-producing fruit such as apples or tomatoes, etc.

TABLE 7–3. CUCUMBERS: Summary of Growing Recommendations

	Germination	Plant Raising	Transplanting	Harvesting Stage	Full Harvest
Temp.(°C)					
day °C	28°C	24 °C	25 °C	23°C	23°C
night °C	28°C	21 °C	25°C	21°C	21–17°C
EC (mS/m)	0.0–1.0	1.0–2.5	2.5	2.5–3.0	2.1–2.8
pH		5.8	5.8	5.8	5.8
Vol. of feed (L/day)*		0.2–0.3	0.2–0.3	1.0–1.5	1.5–2.5
Feed Schedule		A	B	C	D

*as required (watering strategies)

TABLE 7–4. Fertigation Schedule for Cucumber (ppm nutrient)

	N	NH_4	P	K	Ca	Mg	Fe	Mn	Zn	B	Cu	Mo	S	Cl	HCO_3
A. Slab Saturation	200	10	50	253	247	75	0.8	0.55	0.33	0.5	0.05	0.05	120	0	25
B. For 4–6 wks after planting	180	10	50	370	210	75	0.8	0.55	0.33	0.5	0.05	0.05	120	0	25
C. Normal Feed	190	22	50	370	190	65	0.8	0.55	0.33	0.5	0.05	0.05	120	0	25
D. Heavy Fruit Load	210	22	50	370	190	75	0.8	0.55	0.33	0.5	0.05	0.05	120	0	25

	Kg/1000 L (Dilute 1:100)			
Fertilizer	**A**	**B**	**C**	**D**
Calcium nitrate	112.11	92.67	82.11	82.11
Potassium nitrate	25.72	31.5	40.89	56.27
Monopotassium phosphate	6.75	6.75	6.75	6.75
Potassium sulphate	25.77	44.05	37.19	25.95
Magnesium sulphate	66	66	56	66
Ammonium nitrate	0	4	8	8
	g/1000 L (Dilute 1:100)			
Iron chelate 13%	407.69	407.69	407.69	407.69
Manganese sulphate	165.38	165.38	165.38	165.38
Zinc sulphate	91.43	91.43	91.43	91.43
Borax	246.67	246.67	246.67	246.67
Copper sulphate	16	16	16	16
Sodium molybdate	10.87	10.87	10.87	10.87
Desired EC (mS/cm)	2.5–3.0	2.5–3.0	2.0–3.0	2.5–3.5
Desired pH	5.8	5.8	5.8	5.8
Vol of Water (L)	0.25-0.50	0.5-1.0	2.0-3.0	2.0-3.0

Use this table as a guideline only. Fertilizer schedules must be tailored to the individual operation and will depend upon factors such as: source of water, culitvar grown, time of year, etc.

8. Pepper Crop

Greenhouse-grown sweet peppers are increasing in popularity with the Ontario consumer, providing an alternative to tomatoes and cucumbers. Fully matured, red– or yellow–coloured fruit are harvested, but other colours such as orange are also grown.

Cultivars

Select cultivars based on yield potential, fruit size, shape and quality, plant habit, vigour, colour desired by the marketplace, disease tolerance, especially viruses. The most commonly grown cultivar is the large, blocky, mainly red, pepper.

See the OMAFRA Web page or your seed company for more details on cultivars.

Crop Schedule

Since peppers are very slow growing, use a year-round greenhouse pepper schedule. Typically, sow seeds in early October, transplant into the greenhouse in early December, and harvest the first fruit beginning mid-March, and ending late November/early December.

TABLE 8–1. Pepper Crop Schedule

Crop Type	Sow	Plant	Harvest	Terminate
all year	1st wk. Oct.	1st wk. Dec.	mid-end Mar.	1st wk. Dec.

Overwinter production of pepper, (harvesting during December, January and February), without supplementing lighting is not recommended as ambient light levels are too low to sustain an economic yield. At this time, supplemental high-pressure sodium lighting is not being used in Ontario to sustain yields.

Plant Propagation

Sowing

Use seed of high quality from a reputable seed company. Sow the seed in rockwool plugs. Prior to sowing, thoroughly soak these plugs with either plain water or a complete nutrient solution at pH 5.8 and EC 1.0 mS/cm. After sowing, cover the rockwool plugs with medium vermiculite, soak, then cover with a 2–mil clear poly sheet and place on benches with bottom heat or in germination chambers. The optimum germination temperature is 25°C–26°C. Once emergence occurs (after 3–4 days), remove from the germination chamber or remove the poly coverings, and reduce the temperature to 23°C. Transplant the seedlings once the cotyledon leaves are fully expanded and the true leaves begin to emerge (approximately 14–18 days after sowing).

Plant Raising

After the rockwool blocks (10 x 10 x 7.5 cm) are soaked with a complete nutrient solution (EC 1.5–2.0 mS/cm; pH 5.2). Place the seedlings directly (no bending of stem) into the hole and put vermiculite at the base of the stem to provide support. There is an increase in the number of operations that bend the seedlings into the hole to increase stability of the plant in the rockwood block.

Initially, place the blocks close together to conserve space. As the young plants grow, space the blocks further apart to a final spacing of 18 plants/sq. m. prior to transplanting into the greenhouse. During this phase, the optimum night temperature is 20°C with a day temperature of 21°C –23°C. Adjust these temperatures based on available light and the desired growth. Apply a complete nutrient solution to the transplants as necessary. The amount of solution and frequency of application is determined by the temperature, available light, greenhouse conditions, and plant size.

Carbon dioxide supplementation (700–800 ppm) and supplementary high pressure sodium lighting at 20 watts/m^2 greatly improves transplant vigour and size, as well as decreases the time required (1–2 weeks) to attain an ideal transplant. Pepper plants are ready for transplanting when the first flower bud (king flower) is clearly visible or about to open at the first branch on the pepper plant, which usually occurs 6–8 weeks after sowing. [*Plate 13*]

Plant Spacing

A plant density of 3 plants/m^2 is considered optimal because plants are normally trained as a 2 stemmed plant, resulting in 6 stems/m^2. Arrange the greenhouse plants as twin growing rows 0.6 m between growing rows and 0.9 m wide walkways. Adjust plant spacing within the row to obtain the desired plant density. In rockwool culture, use 5 plants/180 cm slab — usually two, 90 cm slabs in a 2 m long poly sleeve to form a single long slab. Space the long slab, as well as the stems, to obtain the desired plant density. Increasing the stem density from 6.0 stems/m^2 to 6.5–6.75 stems/m^2 by adjusting the spacing between the slabs is also an option. Train the stems to allow maximum light interception.

Growing Media

In Ontario, most of the pepper acreage is grown in rockwool or foam with a few acres in NFT. Soak rockwool slabs with the slab saturation solution at pH 5.2, and EC 2.0 mS/cm. [See *Table 8-3*] After transplanting, use a nutrient solution with a suggested pH of 5.2 and an EC of 2.0–2.5 mS/cm. Adjust the EC based on rate of plant growth and available light. Too low an EC results in weaker plants susceptible to disease infestations. Too high an EC restricts growth, resulting in shorter internodes, thinner stemmed plants, and thin and smaller leaves. A limited canopy is of concern because fruit exposed to sunlight may be damaged due to sunscald. [*Plate 14* and *Plate 15*]

Moisture management of the transplant blocks is important to reduce the accumulation of salts at the base of the plant [*Plate* 16]. This damaged area may be the entry point for stem rot diseases such as fusarium stem rot. During the production cycle, use a nutrient solution with a pH of 5.2–5.5, and an EC ranging from 2.0–3.0 mS/cm. Maintain a slab pH of 5.8 and EC of 2.0–3.0 mS/cm. This is achieved by adjusting the percent leach (see Section 4, *Rockwool Culture,* page 31).

The volume and EC of the nutrient solution applied varies depending upon the available light, the size of the plant, as well as the greenhouse temperature and relative humidity. Apply a nutrient solution at 18°C–22°C. Begin irrigation 1–2 hr after sunrise and end 1–2 hr before sunset. Night watering may be required, especially when the heat demand is high on cold, windy nights and/or the relative humidity is low in the greenhouse.

Training and Pruning

Pepper plants, by nature, are multi-stemmed. Young plants branch after several weeks' growth, usually about the 6th–8th leaf stage. Subsequently, at every node a flower bud and a lateral branch or sideshoot develops. Remove these to create a 2–stemmed plant (about 2 weeks after transplanting). Flowers are not allowed to set until the 3rd or 4th node after the initial branching. Remove the flowers by adjusting temperatures (see *Climate*, page 60) or by hand. Do not allow the king flower to develop into a fruit in order to allow a larger plant to develop before fruit setting is encouraged. Remove the lateral branches or sideshoots by snapping or if large, cut off with a sharp knife. Conduct this process every 10–14 days.

Under certain situations, allow side shoots to develop. This choice depends on several factors. To increase leaf area the side shoot may be trimmed to allow one leaf to develop. In some cases, a flower at the first node of the side shoot can be left to develop into fruit in an attempt to ensure fruit is developing at all levels (nodes), especially if the flower at the main stem node does not develop.

Pepper plants must be supported with twine tied at the base of the plant using a loose, non-slip knot and attached to the overhead wires 3.4–3.7 m above. Twist the twine around the plant in a loose spiral every 10–14 days. Operations without high wires can grow peppers by layering the plants similarly to tomatoes.

Climate

Peppers, by nature, are slow growing. They require a high temperature and fertility program to maintain a reasonable growth rate. Fruit quality and yield is determined by the ability to develop large, well-shaped flowers on strongly growing plants. Flowers formed on weak plants are usually smaller, poorly coloured and tend to drop off, or if they develop into fruit, result in smaller and poorly shaped fruit. Improper pollination resulting in poor seed set also produces misshapen fruit.

After transplanting onto the slabs, maintain air temperatures of 23°C/21°C day/night for 1 week to promote strong vegetative growth and rapid root establishment. This initial temperature regime discourages fruit set allowing for a better-balanced plant (see *Fruit Set*, page 60). Approximately 7–10 days after transplanting gradually lower the night temperature to 20°C–18°C to encourage fruit set. A lower night temperature encourages strong flowers and good fruit set. To balance the fruit load:leaf area, manipulate the night temperature to adjust flower development and fruit set. To increase flowering (generative), use a lower night temperature while a high night temperature encourages a vegetative growth.

Pepper plants will flower at every node and sets fruit in flushes (i.e., about 4 fruit/stem). Flowers on the following 2–3 nodes will abort and then the plant will set fruit again. Manipulating the greenhouse environment to improve plant balance minimizes this gap. Removing flowers and/or poor quality fruit is also helpful in balancing the plant and ensuring a steady harvest.

A ventilation temperature 2°C –3°C above the heating set point is generally recommended, but may be adjusted to maintain optimum relative humidity (RH). A vapour pressure deficit (VPD) of 0.4–0.7 kPa is recommended. At the suggested growing temperature, this results in an RH of 70%–80%. In the early planting stages, the RH may be too low, making it necessary to use a temporary 2–mil clear poly as a humidity/thermal screen above the crop to raise the RH. Alternatively, fogging or misting the greenhouse also raises the RH. However, excessive RH increases disease problems.

Given how sensitive pepper plants are, it is important to have all the equipment necessary to maintain an optimum greenhouse environment. While a well-designed forced air heating system (i.e., one with heat delivery system in between the growing rows) may be used, it requires high management skills.

To maintain the desired greenhouse environment during the summer months, screening or shading is necessary. A movable screen or shade curtain, activated when the light and temperature levels are high, decreases stress in the pepper plants. Another option is to whitewash the greenhouse roof. Apply a low-level whitewash late April or early May and a second coat early/mid June. In late August, remove the whitewash to maximize light penetration in the fall. Maintaining ideal conditions during periods of high temperature and light allows the plant to develop a good canopy -minimizing blossom end rot (BER) and sunscald. [See *Table 8-2*, page 61, for a summary of growing recommendations.]

Fruit Set

Fruit set in early-planted crops is delayed to the 3rd or 4th node on the main branches. Remove any flowers set below this level early in their development. This ensures the plant has sufficient leaf area to sustain the developing fruit load without causing a decrease in rate of growth and fruit development. Too early a fruit set results in small, poorly shaped fruit and increased susceptibility to blossom end rot (BER).

Harvesting and Storage

Harvest greenhouse peppers when they are fully coloured (> 80% colour is present). Too early a harvest delays maturity and shortens the crop's shelf life. The highest financial return is obtained when harvested peppers are fully coloured.

Harvest peppers by cutting the fruit stalk with a small sharp knife. A clean, smooth cut decreases the incidence of disease pathogens and provides a pleasant appearance to the harvested fruit. Cut all fruit stalk stubs flush to the main stem. This encourages rapid healing and reduces diseases such as fusarium stem and fruit rot, or botrytis grey mould.

Fruit is graded to size and colour to ensure a uniform attractive product. Store peppers at 7°C –8°C if necessary. Ethylene released from fruit and vegetables stored with peppers may cause pepper fruit to over-ripen, decreasing shelf life and marketability.

TABLE 8–2. PEPPERS: Summary of Growing Recommendations

	Germination	Plant Raising	Transplanting	Harvest Stage	Full Harvest
Temp.					
Day °C	25°C	21°C	21°C	21°C	21°C
Night °C	25°C	23°C	24°C	24°C	18°C
EC (mS/cm)	0.0–1.0	1.0–2.0	1.5–2.5	2.0–3.0	2.0–3.0
pH	5.8	5.8	5.8	5.8	5.8
Vol. Of feed (L/day)		0.2–0.3	0.2–0.3	0.5–1.5	1.5–2.0
Feed Schedule		A	B	C	D

TABLE 8–3. Fertigation Schedule for Peppers (ppm nutrient)

	N	NH_4	P	K	Ca	Mg	Fe	Mn	Zn	B	Cu	Mo	S	Cl	HCO_3
A. Slab Saturation	200	10	50	253	247	75	0.8	0.55	0.33	0.5	0.05	0.05	120	0	25
B. For 4–6 wks after planting	180	10	50	370	190	75	0.8	0.55	0.33	0.5	0.05	0.05	120	0	25
C. Normal Feed	190	22	50	370	190	65	0.8	0.55	0.33	0.5	0.05	0.05	120	0	25
D. Heavy Fruit Load	210	22	50	370	190	75	0.8	0.55	0.33	0.5	0.05	0.05	120	0	25

	Kg/1000 L (Dilute 1:100)			
Fertilizer	**A**	**B**	**C**	**D**
Calcium nitrate	112.11	82.11	82.11	82.11
Potassium nitrate	25.72	42.43	40.89	56.27
Monopotassium phosphate	6.75	6.75	6.75	6.75
Potassium sulphate	25.77	36.06	37.19	25.95
Magnesium sulphate	66	66	56	66
Ammonium nitrate	0	1	8	8
	g/1000 L (Dilute 1:100)			
Iron chelate 13%	407.69	407.69	407.69	407.69
Manganese sulphate	165.78	165.78	165.78	165.78
Zinc sulphate	91.43	91.43	91.43	91.43
Borax	246.67	246.67	246.67	246.67
Copper sulphate	16	16	16	16
Sodium molybdate	10.87	10.87	10.87	10.87
Desired EC (mS/cm)	2.5–3.0	3.0–3.5	2.5–3.5	2.5–3.5
Desired pH	5.8	5.8	5.8	5.8
Vol of Water (L)	0.25-0.50	0.5-1.0	1.0-2.0	1.5-2.5

Use this table as a guideline only. Fertilizer schedules must be tailored to the individual operation and will depend upon factors such as: source of water, culitvar grown, time of year, etc.

9. Lettuce Crop

Today, commercial greenhouse lettuce production is mainly grown hydroponically. In the past, soil production was popular, especially following a spring, soil-grown tomato crop. This kept staff busy and provided extra cash. However, changes to monoculture and hydroponic tomato production ended this practice. At present, lettuce production is conducted exclusively as a single operation. Currently, the butterhead — known as Boston or Bibb lettuce — is the only type grown in the greenhouse. This type forms a loose head consisting of small tender leaves surrounded by the larger outer leaves rather than a tight head.

Greenhouse lettuce is primarily marketed to exclusive niche markets such as upscale restaurants, and fruit and vegetable markets, although increasingly more product is being shipped and sold by the supermarkets.

The average operation size is about 2,500 m^2, with the majority of production conducted in nutrient film technique (NFT) culture. In this system, plants are grown in a recirculated, continuously flowing film of nutrient solution.

Successful marketing of greenhouse lettuce requires a system designed to provide a continuous supply. This is accomplished with a 2–stage production system that has:

- a plant raising section where weekly seeding is conducted and transplants are raised,
- a production section where transplants are grown to maturity and harvested.

To maximize efficiency plant spacing is adjusted according to plant age/size. In the early stages of production the plants are grown close together (4 in. x 4 in. or 100 cm^2 spacing) and then are moved further apart once the leaves touch (8" x 8" or 400 cm^2) until harvest. To provide an average of 1,000 heads of lettuce per week, a growing area of 325 m^2 (3,500 sq. ft.) is required. This results in 8–10 production cycles per year. [See Figure 9-1, *Lettuce Yield Projection for Southwestern Ontario*]

Plant Raising

Sow seeds in flats containing a peat-perlite mixture by placing seed on the media surface and covering them with a shallow layer of fine peat. Soak the flats with plain water at 18°C prior to sowing to prevent disturbing the seed distribution. Then cover the flats with a 2–mil clear poly to retain moisture in the media. A germination temperature of 15°C–18°C is optimal. Lettuce seed may not germinate if the temperature is too high. This is especially true in the summer. Decrease the temperature by shading the germination area or using misting systems.

After the first true leaves emerge (7–10 days), select the best seedlings and transplant in oasis or rockwool mini-blocks (3 x 3 x 3 cm). In some cases, seed can be sown directly into the oasis or rockwool mini-blocks or forestry seedling Jiffy 7's. For the Jiffy discs, place in a flat, soak with tap water, and once fully swollen,

FIGURE 9-1. Lettuce Yield Projection for Southwestern Ontario

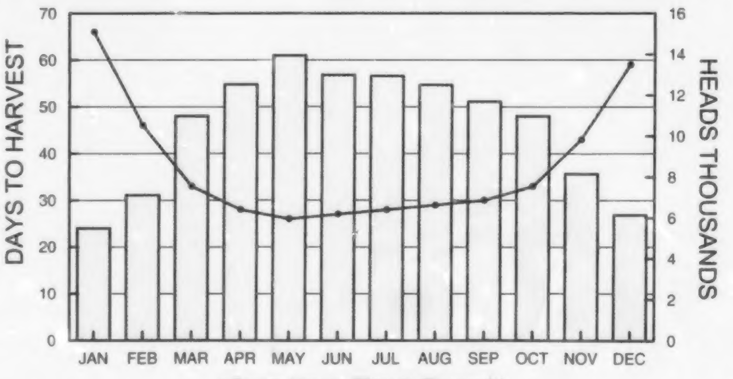
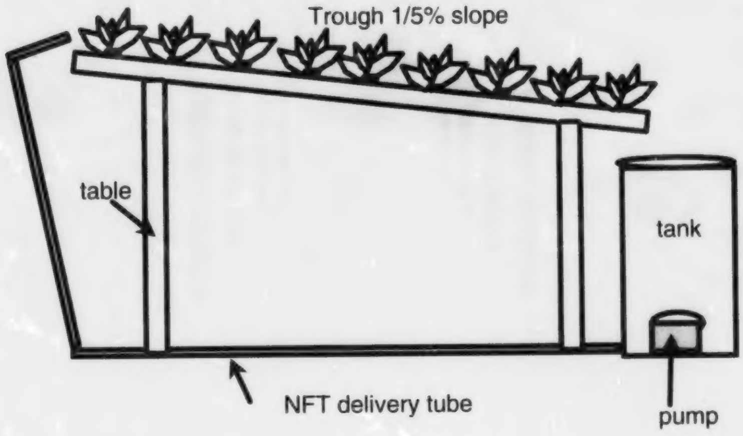


FIGURE 9-2. NFT Layout for Lettuce



place 2–4 lettuce seeds (usually leaf lettuce) in the opening at the top.

Once seedlings reach the desired size, place the plugs in NFT troughs. Water the seedlings with a dilute complete nutrient solution (EC 1.0–1.5 mS/cm and pH 6.0) by overhead misting or sub-irrigation. Maintain a 15 °C–18°C temperature and supplement with HPS lighting at 20 watts/m^2 (24 hr photoperiod) and CO_2 at 1000 ppm.

The 24 hr photoperiod, especially under low light levels in winter and cloudy days, enhances plant growth and decreases time to planting. Move young plants to permanent troughs after 3–4 leaves emerge (usually 3–4 weeks after sowing). Depending upon the seasonal solar radiation, growing temperature and CO_2 supplementation, harvesting can begin 4–8 weeks later. During summer, the time between sowing to harvest can be as short as 7–8 weeks, while in the winter it may be as long as 11–12 weeks.

Crop Production

There are numerous NFT trough systems designed for lettuce production. These may be as simple as a 10 cm (4 in.) PVC drainage pipe or an eaves trough to an extruded trough with a channeled floor and built-in plant supports. In all cases, the trough provides a channel for the recirculating nutrient solution to flow and a support for the placement of the transplant (usually a cover through which the transplant is placed). The trough must be rigid enough to be moved (for adjusting plant spacing as the plants grow) as well as to be disinfected between crop cycles. [See Figure 9-2, *NFT Layout for Lettuce*]

Aeration of the root system is important. Thus, the system must be designed to provide a shallow film of fast flowing nutrient solution. If the film is too deep, a greater number of roots are submerged, resulting in poorly–aerated roots. These roots are weak, brown in colour, easily broken and prone to microbial infestation.

Aerate the nutrient solution in the mixing tanks by using a small pump that recirculates the solution back into the mixing tank via an overhead shower head type structure. An aerator — a device that increases the air in the solution as it is pumped back into the reservoir tank — can also be used. Design the return line and the reservoir tank so that the return water splashes into the reservoir tank, increasing aeration and mixing.

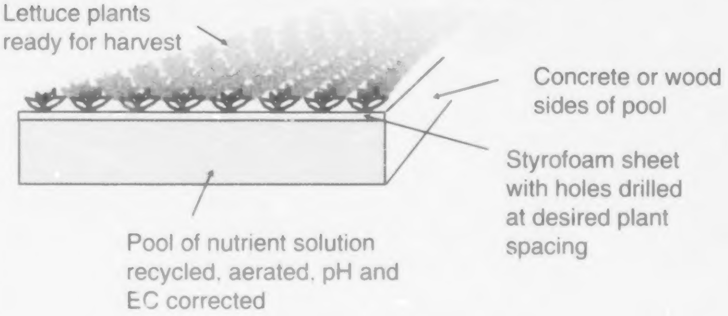
The mixing tank or reservoir needs a capacity of 2,000–2,300 L/ac (1,000–1,500 L/1,000 m^2) to ensure adequate solution reserve and to provide a rapid response to EC and pH adjustment. Too large a reservoir tank may not respond rapidly to automatic additions of fertilizer and acid during production. Control pH and EC levels automatically to ensure optimal EC and pH ranges and to decrease EC fluctuations that promote tip burn. The EC level of the nutrient solution varies depending upon the time of year, stage of crop production, cultivar, and rate of growth. Table 9-1 provides a fertilizer schedule for lettuce production.

An alternative production system for greenhouse lettuce is the floating culture. [Figure 9-3, *Float Raft Production System*] This method uses styrofoam sheets with holes drilled at specified plant densities that are floated in pools of nutrient solution. This system can be:

- 5 x 15 cm (2 x 6 in.) pressure treated lumber designed like a backyard hockey rink, lined with plastic or
- elaborate concrete pools 30 cm deep or
- ebb and flow tables altered to maintain a deeper water pool (3–5 cm).

The nutrient solution is recirculated, aerated, amended with fertilizers and acids to maintain the desired nutrient solution composition. The length and width of the pools varies to fit available space in the greenhouse or determined by the materials used. This system produces very successful crops.

FIGURE 9-3. Float Raft Production System


Lettuce plants ready for harvest
Concrete or wood sides of pool
Styrofoam sheet with holes drilled at desired plant spacing
Pool of nutrient solution recycled, aerated, pH and EC corrected

Climate

Temperature regimes of the cropping cycle vary depending on seasonal solar radiation, the cultivar, the desired rate of growth and harvest date. In general, maintain night temperatures of 15°C–18°C with a light dependent day temperature of 18°C–19°C (cloudy days) to 19°C–22°C (sunny days) and begin venting 1°C–2°C above the set temperature. Adjust the temperature regimes to maintain the weekly production goal. Manipulate the temperature gradually to prevent disease or lettuce tip burn incidences.

Lettuce can be grown as a cool crop (10°C night and 15°C–18°C day) especially during the winter months when light levels are low. However, the days to harvest period is extended. Keep the relative humidity between 75%–85% or VPD 0.4–0.8 kPa. During the summer months, when outside temperatures are high, do everything possible to keep a lower greenhouse temperature. Lettuce leaf/head quality is poor at higher plant temperatures.

Shade the greenhouses by using moveable shade curtains, or applying whitewash to the outer greenhouse structure. Use fan and pad cooling systems or high pressure fogging systems. Take care to avoid conditions that result in free water on the leaves or lower transpiration rate.

Supplement with HPS lighting (> 20 watts/m^2) during the low light, winter months and periods of cloudy weather to obtain an 18–hr photoperiod. Keep CO_2 levels of 1,000 ppm during periods of natural and artificial light.

Harvesting and Storage

Once lettuce has reached marketable size (250 g), remove from the trough with the roots attached and place, roots first, in a poly bag. Tie off roots with an elastic band. Leave the bag open around the head of lettuce. Special clam shell clear plastic containers with a small trough for the roots are also available. Lettuce harvested without the roots is bagged bottom first and the top left open. Place the bagged lettuce in boxes containing 12–18 heads for shipping.

Lettuce quality deteriorates rapidly if improperly stored. Lettuce must be stored at 2°C–4°C at high relative humidity (80%–90%). Freezing temperatures damage the product and too high a temperature results in further leaf development, reducing customer appeal. Store lettuce away from ethylene producing products (see *Russet Spot*, page 73).

TABLE 9–1. Fertigation Schedule for NFT Lettuce (ppm nutrient)

	N	NH_4	P	K	Ca	Mg	Fe	Mn	Zn	B	Cu	Mo	S	Cl	HCO_3
A	200	10	50	400	200	55	6	1	0.5	0.5	0.05	0.05	120	100	25

	Kg/1000 L (Dilute 1:100)
Fertilizer	**A**
Calcium nitrate	87.37
Potassium nitrate	52.56
Monopotassium phosphate	6.75
Potassium sulphate	20.41
Potassium chloride	14.17
Magnesium sulphate	4.6
Ammonium nitrate	0.74
	g/1000 L (Dilute 1:100)
Iron Chelate 13%	4620
Manganese sulphate	380.77
Zinc sulphate	142.86
Borax	326.67
Copper sulphate	16
Sodium molybdate	10.87
Desired EC (mS/cm)	2.2–3.0
Desired pH	6.2–6.5

Use this table as a guideline only. Fertilizer schedules must be tailored to the individual operation and will depend upon factors such as: source of water, culitvar grown, time of year, etc.

10. Diseases

Disease control in the greenhouse is easily managed by:

- sanitation and hygiene
- cultural practices such as nutrition and pruning
- greenhouse environmental management.

Plate 17 is an example of a situation that easily leads to disease outbreaks.

Tomatoes

Tomato Diseases Caused by Fungi

Corky Root Rot (*Pyrenochaeta lycopersici*)

Infected plants show a lack of vigor (thin heads), and wilting or flagging on sunny days. As the disease progresses, foliar chlorosis (yellow-brown chlorosis on the lower leaves) and more severe wilting is visible. Examining the roots early reveals light brown lesions on the root surface. These are closer to the base of the plant in older roots. On larger and older roots, dry brown, swollen corky lesions are visible. The corky layer easily peels off revealing the vascular root tissue (stele). This is commonly known as rat-tail.

Corky root is a slow disease and death of the plant takes a long time. That is why crop management is so important. Encouraging aggressive root systems — where new roots are continuously developing —minimizes problems associated with the disease. Do not plant in cold media. In rockwool culture, the infected plant eventually infects the companion plant in the bag. At the end of the season, discard this bag, as steam sterilization may not be able to penetrate the large infected roots where the pathogen is located.

Damping-Off and Late Damping-Off (*Pythium and Rhizoctonia*)

Given the wide use of hydroponic culture, with its inorganic growing media, early damping-off is not a common problem today. Seeds, in general, are treated.

Early damping-off decays the seed or seedling prior to emergence. With late damping-off, the base of the seedling narrows and collapses, causing seedlings to topple. [*Plate 18*]

Minimize the problem by:

- taking proper care at seed sowing
- maintaining the ideal media temperature
- watering with warm water (18°C–22°C)
- using sterile growing media
- using clean water (avoid soil–contaminated water from wells or creeks)
- disinfecting water if not clean
- using media that drains well.

Water the seedlings in the morning so the leaves and stems are dry before nightfall. Keep a clean starter house and sowing bench.

Fusarium Wilt and Verticillium Wilt (*Fusarium* and *Verticillium*)

Initial symptoms are a yellowing of the lower leaves and wilting. The yellowing begins in the older leaves, resulting in epinasty, where the leaves and growing tips bend downwards. Generally, a bright yellow discoloration of the interveinal tissue with brown to orange marks can be seen. There is a brown discoloration in the vascular tissue that extends high up the plant. Leaf petioles may also exhibit vascular discoloration in severely affected plants.

Most greenhouse cultivars today are resistant. However, there have been several reports of verticillium wilt incidence on resistant cultivars in greenhouse tomatoes in Ontario. Greenhouse sanitation is the best remedy.

Fusarium Crown and Root Rot (*Fusarium oxysporum* and sp. *radicis-lycopersici* (FORL))

Plants infected with this disease wilt on sunny days, have a thin head, flaccid leaves and weak flowers. First symptoms are usually seen when plants are fully loaded, at the 6–8 cluster development stage. A chocolate brown discoloration at the base of the plant and ground level is usually visible and the roots are brown. Examination of the vascular tissue (splitting open of the stem base) displays a chocolate brown discoloration that extends 5–25 cm above ground level. [*Plate 19*]

Most modern tomato cultivars have resistance to FORL. However, some desirable cultivars do not; consider grafting onto a resistant rootstock.

Grey Mould (Ghost Spot) (*Botrytis cinerea*)

This common disease affects all aerial components of the plant and is prevalent in greenhouses where the environment and crop management is not optimal. Symptoms may be seen on the stem, leaf, fruit, and harvested fruit truss, as well as any wounds or pruning cuts that have not healed properly.

In most cases, the classical brown lesion, often with concentric banding and grey fungal growth, is readily seen. [*Plate 20*] Early symptoms on the stem are elliptical water soaked lesions from which the mouldy-grey growth develops. Typical early leaf symptoms begin at a point of injury. This can be a result of:

- damage by workers,
- guttation, —exudation of moisture from the leaf edges or tips usually when RH is high/VPD is low and root pressure is high
- or poor greenhouse environment.

As the disease progresses it develops a grey mould that covers the whole leaf. Ghost spot is the term used to describe symptoms on the fruit. This is a light coloured circular mark with a whitish-brown pinpoint in the middle. [*Plate 21*]

Improving greenhouse environment and cultural practices decreases the incidence of *Botrytis cinerea*. *Botrytis cinerea* may infect the plant early in its life cycle (starter house or shortly after transplanting), but may not manifest itself until the plant is undergoing stress. This usually occurs prior to picking, 6–8 weeks after infection has occurred. Management includes:

- adjusting the greenhouse environment
- increasing heating and venting to prevent free water on the plants
- lowering the RH or raising the VPD
- raising the EC
- deleafing early in the day, allowing wounds to dry before nightfall.

Infected stem tissue may be cut out to prevent girdling (where infection completely surrounds the stem), and decrease potential spores.

Leaf Mould (*Fulvia fulva*) (*Syn. Cladosporium fulvum*)

The first symptoms are yellowish-green indefinite areas on the upper leaf surfaces about the lower middle of the plant. This is accompanied by purplish, velvety fungus growth on the underside. These symptoms are very similar to severe magnesium deficiency, and may be confused with it. However, with magnesium deficiency there is no fungal growth on the leaf underside. Leaf mould spreads rapidly under humid conditions and quickly moves towards the top of the plants.

Modern greenhouse tomato cultivars are resistant to this pathogen. However, maintain ideal greenhouse environment conditions to prevent unnecessary infections.

Powdery Mildew (*Erysiphie Orontii*)

This is a recent disease now quite common in Ontario tomato greenhouses. Incidences have occurred as early as the seedling stage. Early symptoms are yellow spots or blotches on upper leaf surfaces, with white coloured powdery growth on the undersurface. In severe infestation, these lesions coalesce to create a white powdery fungal growth on the leaf surface and stem. [*Plate 22* and *Plate 23*]

This disease spreads very rapidly in the conditions optimal for maximum tomato production. At the first incidence, it is advisable to treat the whole operation to minimize long-term problems. [See Section 13, *Pesticides Registered for Greenhouse Vegetables*]

Tomato Diseases Caused by Bacteria

Bacterial Canker (*Clavibacter michiganensis* ssp. *michiganensis*)

This is a very contagious and destructive disease of greenhouse tomato crops. The first symptom is usually a wilting of the upper leaves, one-sided wilting, with areas of dead or dying tissue on lower leaves. [*Plate 24*] In later stages, the fruit may take on a whitish, mottled colour, instead of the normal greenhouse colour of the developing fruit on a normal plant. [*Plate 25*] Diseased fruit often drop off prematurely, especially if the plant is given a sharp shake. Inconspicuous, yellowish coloured pustules or lesions may occur on the surface of the stems and leaves. These contain large numbers of bacteria that are easily carried by workers from diseased to healthy plants. It is important to recognize canker at an early stage and to remove infected plants before a major epidemic occurs.

Isolation is the best management technique to curb the spread of this disease.

- Place infected plants and three neighbouring plants on either side in garbage bags and discard (incinerate or bury).
- Staff who remove the infected plants must shower and change into clean clothes before re-entering the greenhouse.
- Isolate the row from which the diseased plants were removed.
- Do not allow personnel to enter it.
- Assign one person to perform all work in this row. This person must wear coveralls to be used exclusively while working the infected row.
- Limit work in the diseased rows to the end of the day to minimize risk of disease transfer.
- Assign equipment, such as picking carts and boxes/crates, specifically for the infected row, or disinfect before moving into other areas of the greenhouse.

Sanitize properly at the end of the crop to minimize reoccurrence.

Bacterial Stem Rot (*Erwinia and Pseudomonas* spp.)

The first symptom is the sudden wilting of a few plants, scattered throughout the greenhouse. These plants will have hollow stems about 20–40 cm above the ground, have a foul odour and may be filled with decaying plant tissue. In some cases, a dark chocolate brown discoloration may be seen at the nodes. Infected plants tend to be soft vigorous plants and primarily in gutter rows with condensate dripping. Infection usually occurs through a wound where a sucker, leaf or cluster has been removed. [*Plate 26*]

To curb this disease, alter the greenhouse environment by:

- increasing the VPD or lowering RH
- allowing no condensation of water on the plants
- changing the plant vigor with a higher EC, lower water application, and/or applying a low N fertilizer
- keeping plants dry.

This disease is seen in poorly managed crops and greenhouse environments and has not been a major problem in Ontario greenhouses.

Tomato Diseases Caused by Viruses

Mosaic

Tomato mosaic and tobacco mosaic virus were ongoing problems in Ontario greenhouses until the use of resistant cultivars. These diseases spread very easily and are difficult to control. The first symptom is light to dark mottling of the upper leaves together with a thinning out of the upper stem and occasionally wilting. Infected plants are weakened and fruit set is reduced. There are many different strains of mosaic. Mild strains may cause only a slight reduction in yield, whereas severe strains may destroy the plants. The disease is spread from infected to healthy plants mainly by aphids, and also by greenhouse workers. The virus can persist several months on sap stained, dirty clothing.

Most modern greenhouse tomato cultivars are resistant to this disease.

Shoestring (*Cucumber Mosaic Virus*)

This virus produces narrow, spindly, mottled leaves on the upper portions of tomato plants. Infection is common when aphids and other insects move into the greenhouse, carrying the virus from outdoor cucumber or melon crops, or from a number of weed species known as symptomless carriers. Infected plants may not die, but they rarely produce a marketable crop.

Remove infected plants to minimize further spread of the infection and control pests.

Tomato Non-Parasitic Disorders

Blossom End Rot (BER)

Commonly seen as a firm, dry, sunken and discoloured area (brown or black) at or near the blossom end. It may be slight, less than 0.5 cm diameter, to large where over half the fruit is affected. It is caused by the lack of calcium movement to the distal end of the fruit, resulting in poor cell integrity and cell breakdown. The lack of calcium may be due to:

- lack of calcium supply
- high EC (prevents or decreases water uptake)
- low moisture in the growing media and erratic watering strategy
- excessive vegetative growth (majority of calcium moved to the leaves)
- dramatic change in fruit growth resulting in higher calcium demand than the supply to the afflicted tissue
- high VPD (or low RH) resulting in excessive transpiration and decreasing water movement (and calcium movement) to the fruit
- poor root system due to lack of aeration thus decreasing water and calcium uptake. [*Plate 27*]

Blotchy Ripening

This disorder causes a type of uneven ripening, where certain areas on the tomato surface remain green or yellowish-green while other areas develop to their normal colour. Some known causes of blotchy ripening are low fertility levels, inadequate potassium, overcrowding, excessive fruit surface temperature, mosaic and other viruses. [*Plate 28*]

2,4-D Injury

This herbicide was used for many years for weed control in field crops and lawns. Occasionally greenhouse tomato crops are damaged by drifting 2,4-D fumes or from contaminated sprayers. Plant symptoms are often similar to those caused by shoestrong and/or other viruses, where leaf growth becomes spindly, distorted and cork screw-like, blossom set is reduced, and fruit that do set are misshapen.

Catface

This condition occurs during periods when greenhouse temperatures are not maintained at a level adequate for normal fruit setting. Such fruits become misshapen and have irregular protuberances at the blossom end. Streaks and bands of dark greenish, scaly scar tissue often occurs at the blossom end or at the sides of the tomato fruit.

Puffiness

Puffiness or hollow fruit may occur due to inadequate pollination or incomplete nutrition and/or conditions of low light. Frequently only one or two tomatoes on an individual truss may be affected. Fruits on subsequent clusters may not be affected if environmental conditions improve.

Nutrient Deficiencies and Toxicities

An imbalance of nutrients within tomato plants may cause various leaf symptoms that resemble disease. Most common is magnesium deficiency, which causes an interveinal light green discoloration of the older leaves, especially during periods of heavy fruit load. [*Plate 29*] Fortunately, greenhouse tomatoes are able to withstand a certain amount of magnesium deficiency without significant yield loss.

Low levels of calcium result in BER as discussed earlier. (see Section 10, page 66) Potassium deficiency causes the edges of the young upper leaves to display a leaf edge chlorosis as well as blotchy ripening. [*Plate 30*] Iron deficiency may also occur, where leaves at the tops of the plants turn a mottled light green to lemon yellow. [*Plate 31* and *Plate 32*] If severe, this causes a thinning of the upper stems and reduction of fruit set on the upper blossom clusters. A deficiency of manganese produces symptoms similar to iron deficiency. The most common symptom of manganese toxicity is a darkening of the main veins of the younger leaves, plus a browning and destruction of adjacent leaf tissue. Yellow discoloration of the distal leaf with darkening of the midrib is a result of boron deficiency. [*Plate 33*]

Russetting

This disorder is present in some tomato cultivars and can be a problem as fruit quality is adversely affected. Russetting, or shrink cracks, are minute hair-like cracks on the shoulders of tomato fruit. In mild cases, these cracks are visible under indirect light, but in severe cases are readily visible. Russetting can be seen on immature green fruit as well as on mature ripe fruit. [*Plate 34*] In severe cases, the shoulder remains a grey-green colour, while the remainder of the tomato ripens normally. [*Plate 35*]

It is thought that the fruit expands at a rate faster than the ability of the skin to expand, causing these minute cracks to occur. Try to select a cultivar less prone to russetting but able to retain fruit size, plant habit, etc.

Techniques that help minimize russetting are: proper water management, plant balance, fertilizer schedule, and greenhouse environment.

Cucumbers

Cucumber Diseases Caused by Fungi

Black Root Rot (*Phomopsis sclerotioides*)

This disease is quite common in soil grown cucumber crops with unsterilized or unpasteurized soils. However, disease incidence has decreased with the increase of rockwool culture, but it may occur where greenhouse hygiene is poor. This is especially true during the plant raising stage, as contamination with infected soil may occur more readily.

Infected plants exhibit wilted leaves that recover at night. As the disease progresses, the recovery decreases, resulting in weaker heads, poor fruit set, permanent wilting and eventual death. This usually occurs in conjunction with other pathogens. Examination of the roots with a hand lens reveal black rectangular discoloration patterns like a checkerboard along the infected root.

Pasteurizing the growing media and proper hygiene are key methods of decreasing infection.

Damping-Off and Late Damping-Off (*Pythium* and *Rhizoctonia*)

Early damping-off and late damping-off symptoms are similar to those in tomatoes. (see page 66) The same organisms attack the cucumber roots of mature plants in rockwool culture — especially if conditions in the root zone are not properly managed. This results in wilting of the upper leaves during the day (more severe on sunny days) with recovery at night. However, this eventually leads to death. Affected plants also display brown-orange lesions at the base of the plant that may extend 10 cm along the stem. Roots are severely affected and are brown and easily broken off.

Proper water management is the best strategy to minimize pythium problems in mature cucumber plants. Over-watering and poor aeration are the two main causes of pythium in cucumber crops. Adverse root zone temperatures (too low or too high) will also promote pythium infestations. Avoid water that may be contaminated by soil (well or creek). Disinfect this water before use.

Grey Mould (*Botrytis cinerea*)

Botrytis cinerea attacks leaves, fruit and upper stems of cucumber plants, and is a result of poor crop management and environmental control. Classical botrytis grey mould symptoms (brown lesions with grey fungal growth) are visible at wound sites (nodes, fruit stems, broken leaves) and in severe cases on the flower and tip of fruit. [*Plate 36*]

Heat and ventiation as well as proper pruning of stems and fruit stalks (clean cut without ragged edges) is the best way to minimize the incidence of *Botrytis cinerea*.

Gummy Stem Blight (*Didymella bryoniae*)

This is a common greenhouse cucumber disease, prevalent in most greenhouses. It is readily managed through proper cultural practices and environmental conditions. The disease attacks the stem, leaves, flower and fruit. Symptoms are similar to botrytis. However, a key difference is that on the stem, black pinpoint lesion spots (fruiting bodies of the fungus) are seen when viewed with a hand lens. Lesions on the stem may also exude tan-yellow coloured clear crystals. The leaves show a V-shaped yellowish-brown dying tissue. Usually, the fruit does not show any visible external injury; however infected fruit tend to have a pointy blossom end. A brownish-yellow discoloration of the centre tissue is seen on the infected fruit when the blossom end is cut along its length. [*Plate 37* and *Plate 38*]

The pathogen may survive up to 2 yr. in a dormant stage in undecomposed plant debris that is a source of inoculum. Gummy stem blight pathogen requires a wound site to enter the plant and cause damage. Under ideal conditions, 1 hr of leaf wetness is all that is required for infection to occur. Symptoms may take 3–10 days to display. Either cut out infected sites on the stem or remove infected plants. Minimize infection by adjusting the greenhouse environment to eliminate free water on the plants. Clean cut surfaces at the nodes, fruit stalk, etc. to encourage early healing of the wound.

Penicillium Stem Rot (*Penicillium oxalicum*)

This is a relatively new disease in Ontario cucumber greenhouses, and has resulted in extensive plant death in some operations. Disease symptoms are similar to those of grey mould and gummy stem blight, but differ as a bluish-grey fungal growth is usually visible at the lesions. These lesions may occur anywhere along the stem, but are commonly seen at the base of the plant (10–15 cm above the block) and/or 1.0–1.5 m from the ground.

The disease usually attacks a pruned node and the infected tissue may extend 10–15 cm above and below the infected node. Extensive internal tissue rot results in death of the plant above the infected point. Remove the infected tissue up to 1–2 nodes below the infected node to allow a new sucker to develop. [*Plate 39*] This may reduce yield.

Cultural practices, especially during the plant raising stage, are critical in minimizing or eliminating the disease incidence. Grow transplants under high light, low RH or high VPD (0.6–0.8 kPa); feed with a nutrient solution with a high EC and keep a bit on the dry side. Adjust the greenhouse environment to minimize or eliminate free water on the plants and maintain a higher VPD (0.6–0.8 kPa). Prune with a sharp knife that is frequently disinfected to minimize disease transfer.

Leaf Spots

Several air-borne fungi, including species of *Alternaria* and *Colletotrichum* (Anthracnose) may cause round areas of dead tissue on cucumber leaves. [*Plate 40*] In severe cases, the spots may enlarge, grow together and destroy the total leaf surface. Downy mildew fungus causes somewhat similar spots, frequently in crops planted in August and September. Downy mildew, however, usually attacks the lower leaf surfaces and can be identified by the purplish spore growth it produces.

All of the above-mentioned leaf spots are most severe in areas within the greenhouse where there is poor air movement and high humidity. Fall crops are more prone to attack, especially when "sweating" occurs due to cold nights following warm, humid days.

Powdery Mildew (*Sphaerotheca fuliginea*)

This is one of the most common and serious diseases of greenhouse cucumber crops. All Ontario greenhouse cucumber growers experience incidences of powdery mildew during the cropping cycle. The first symptoms are small white powdery spots that appear on the upper surface of the leaf. These spots rapidly expand and spread to other leaves and can quickly cover the whole leaf and even the stem and fruit in severe cases. [*Plate 41*]

Dry greenhouse conditions tend to promote the spread of the disease through sporulation, whereas free water on the leaf surface increases the rate of infection.

It is difficult to use chemicals to control powdery mildew as the disease rapidly becomes resistant. Use powdery mildew tolerant cultivars to assist in managing this disease. Applying water to the leaf surfaces, i.e., washing down the crop with water, helps decrease the disease incidence, but may increase the incidence of other fungal diseases such as gummy stem blight and botrytis. This should only be done when rapid drying is assured.

Downy Mildew (*Pseudoperenospora cubensis*)

This is a common problem in fall cucumber crops, and is prevalent in greenhouses with inadequate ventilation. Symptoms are angular, light green areas, bordered by leaf veins, which turn yellow. A purplish fungal growth may be seen on the under surface of the leaves.

Adjust the greenhouse environment to increase air movement and minimize free water on plant surfaces.

Fusarium Root and Stem Rot of Cucumbers (*Fusarium oxysporum* f.s.p. *radius–cucumerinum*)

This is a relatively new disease in Ontario greenhouses. The upper leaves of the plant wilt and plant vigour declines. The base of the stem has pale tan-pinkish hue streaks that extend at least 20–30 cm upwards, and may girdle the stem. The underlying tissue is soft and emits a slight odour. [*Plate 42*] Affected plants have brown to black coloured roots. The root tips are affected first.

This fungus may colonize rockwool blocks. Greenhouse sanitation is the key in minimizing infestations. Implement precautions similar to bacterial canker in tomatoes (page 67) to prevent widespread incidences.

Cucumber Diseases Caused by Bacteria

Bacterial Wilt (*Erwinia trachilphila*)

Symptoms are a sudden collapse of the entire plant, or sometimes one or several leaves may wilt first. There is no recovery. The striped and spotted cucumber beetles are the key carriers of this disease. The bacteria live in the beetles and infect the plant once the beetle feeds on it. Upon entering the plant the bacteria reproduces rapidly in the plant's vascular tissues, producing gums that eventually block the vascular tissue, resulting in the collapse of the plant.

To control bacterial wilt, control the cucumber beetle by treating vegetation outside the greenhouse and isolate infected plants. It also helps to screen the vents against the beetle.

Cucumber Diseases Caused by Viruses

Cucumber Mosaic Virus (CMV)

In Ontario, this is a common problem in greenhouse cucumber production, and is usually associated with aphid infestation (especially when fall crops are planted). The virus has a wide host range and aphids are one of the key agents of infection. Infected leaves and fruit display a light and dark green mottling, and the plant tends to lose vigor (thin, spindly growth, weak flowers and abortion of newly formed fruit), and eventually die. [*Plate 43* and *Plate 44*] A sudden wilt of whole cucumber plants may occur, and is considered a result of a combined infection of CMV and pythium.

To control infection, eliminate or minimize the inoculum source (alternative hosts) near the greenhouse. Screen greenhouse vents to prevent aphid invasion, or spray the greenhouse vicinity to decrease aphid populations.

Pseudo Yellows Virus

This virus is spread by the greenhouse whitefly. Symptoms are chlorotic yellowing between the veins of older leaves and interveinal yellow spotting on intermediate leaves. [*Plate 45*] Upper leaves may remain unaffected during the early stages. Diseased plants become less productive.

Watermelon Mosaic Virus

Symptoms include distortion of the terminal growth, interveinal blister-like protrusions on the older leaves and severe distortion and bump-like protrusions on the developing fruit. The sources of infection are not yet fully identified, but other plants (e.g., alfalfa and certain weed species) are suspected of harbouring the virus. It can be aphid transmitted.

Cucumber Non-Parasitic Disorders

Nutrient Deficiencies and Toxicities

A shortage of one or more of the major or minor elements necessary for plant growth may produce symptoms that resemble disease. One of the more commonly occurring deficiencies is magnesium, where certain cucumber cultivars develop areas of lighter green colour in the mid- section of the plant. This symptom is most pronounced on the older, fully developed leaves. Younger leaves near the tops of the plants and on suckers remain a normal green colour. Although the symptom may cause concern, especially to new growers, magnesium deficiency is seldom serious.

Calcium deficiency is a common problem in cucumber production, especially in the younger rapid growth stage. [Plate *46*] The upper leaves are rounded and cupped downwards, and may have light brown–yellow discoloured edges.[1] To minimize this problem, increase the supply of calcium in the fertility program in the early stages of the cropping cycle.

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[1] The growing point dies in severe cases.

Occasionally, deficiencies of one or more of the minor elements may occur, especially when plants are grown in rockwool or other artificial media. If adequate amounts of minor elements are not included in the feeding solution, iron deficiency may occur. [*Plate 47* and *Plate 48*] Manganese deficiency has also been noted on occasion.

Toxicity symptoms may also occur if one or more of either the major or minor elements is supplied in excess. Severe toxicities usually result in a burning out of leaf tissue. If deficiencies or toxicities are suspected, send leaf samples for tissue analysis. Damage due to fungicides may also occur.

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Peppers

Pepper Diseases Caused by Fungi

The most common greenhouse diseases, pythium and botrytis [*Plate 49*] can affect pepper plants similar to tomatoes and cucumbers, with similar symptoms displayed. However, the following diseases are specific to peppers and can be problematic in greenhouse pepper production

Fusarium Stem and Fruit Rot (*Fusarium solani*)

This disease can cause severe economic loss in greenhouse peppers if action is not taken. Early symptoms are lack of vigor, partial wilting of upper leaves on sunny days with slow or delayed recovery. Dark brown sunken lesions are visible on the stems at leaf nodes. [*Plate 50* and *Plate 51*] Fruit have a more flattened shoulder, longitudinal pale or brown striations and rot beneath the calyx.

Powdery Mildew (*Leveillula taurica*)

This disease has recently been in seen in Ontario, and is likely to become a serious problem. Early symptoms are mottled yellow and light green areas on the upper leaf surface, followed by white, powdery fungal growth on the lower surface. Control measures similar to tomato and cucumber powdery mildew are effective. [*Plate 52*]

Pepper Non-Parasitic Disorders

Elephant's Foot

The name aptly describes the symptoms. The base of the stem at the point of entry into the growing media is flared, with the outer tissues peeling back, revealing dark brown-coloured soft rot. The affected plants have a reduced vigor and are more prone to diseases such as botrytis and fusarium stem rot. Fungus gnats are also attracted to this rotting tissue, and may increase the incidence of pythium. [*Plate 16*]

This disorder is often seen on plants that were raised under "soft" conditions in the starter house.

Blossom End Rot

This disorder is seen at the blossom end of the fruit, as well as on the sidewalls close to the blossom end of the fruit. [*Plate 53*] A grey, water soaked area is an early indication of damage. This area proceeds to become sunken and have a tan to grey colour. Take corrective measures similar to tomatoes.

Sunscald

This disorder is easily confused with blossom end rot as the symptoms are very similar. Usually sunscald symptoms are seen on the sidewall of the fruit and have a distinct edge, with a dry yellow–tan discoloured sunken area within. [*Plate 14*] This disorder is a result of young fruit exposed to direct sun. Increase leaf area to protect the fruit and use shade curtains (if available) or whitewash the exterior roof of the greenhouse to alleviate the problem. Sunburn is also a result of poor canopy and direct light on the fruit surface. [*Plate 15*]

Fruit Cracking and Pointed Tip

Internal fruit growth and irregular watering can cause fruit to split. Low temperature regimes may cause fruit to develop pointed ends, degrading fruit quality. [*Plate 54* and *Plate 55*]

Nutrient Deficiencies and Toxicities

Pepper plants are slow growing and will take a long time to display deficiency symptoms after a nutrient is missing in the fertilizer program. It takes just as long to recover once corrective measures are implemented. It is important that all ingredients for the fertilizer program are included at all times. *Plate 56* and *Plate 57* are examples of what happens when nutrients are left out of the fertilizer program.

Lettuce

Lettuce Diseases Caused by Fungi

Botrytis and downy mildew are two of the most common diseases that affect lettuce. Greenhouse environment management is the key technique to control and manage these problems.

Pythium

This can be a problem in NFT systems if the system is improperly designed, poorly managed (flow rate, solution temperature, aeration) and the plants are overly stressed. The affected plants wilt and have brown discoloured roots that fall apart when touched. The disease can spread rapidly through the production house. UV lamps to disinfect the nutrient solution work well.

Physiological Disorder

Lettuce Tip Burn

This disorder is commonly seen in greenhouse lettuce production. The usual symptoms are the browning of the edges and tips of the young lettuce leaves. In severe cases, they coalesce to cause severe tip burn. Lettuce tip burn is caused by the lack of calcium translocation to the developing leaves. Any factors that have a positive influence on calcium translocation minimize lettuce tip burn. Increased transpiration increases calcium translocation to the leaf tip, decreasing visual symptoms. Transpiration can be increased:

- through ventilation
- by increasing air circulation around the leaf surface using horizontal air flow fans or turbulators
- by maintaining a slightly greater VPD or lower RH.

Once leaf tip burn symptoms are observed, they do not disappear, and cannot be masked by sprays, etc. Prevention is the key to eliminating lettuce tip burn.

Russett Spot

This is a problem common to lettuce in storage during shipping and handling. Tan brown spots appear at the veins of the lettuce and, in severe cases, can coalesce to give an unappealing product. This is caused by too low a storage temperature resulting in chilling injury and may also be caused by ethylene present in the storage facility.

11. Integrated Pest Management

Integrated Pest Management for Greenhouse Vegetable Crops

IPM is a pest control philosophy that uses all available control strategies to maintain pest populations of insects, mites, or disease organisms below an economic injury level. It does not advocate a continuous pesticide spray program to "eradicate" pests, but promotes the integration of cultural, physical, biological, and chemical control strategies.

The routine spraying of pesticides for "insurance" purposes is no longer likely to achieve effective control. In recent years, this practice has led to a number of problems, which include resistance, environmental damage, and personal health and safety.

Resistance

Insects can develop resistance to any synthetic pest control product. Manufacturing new pesticides takes significant time and resources, and therefore it is essential to use available pesticides as minimally and as efficiently as possible to prolong their useful life. If not properly managed, pesticides can be lost much faster to resistance than chemists can develop them.

Environmental Damage

Concerns over environmental pollution and ground water contamination make it important to reduce the use of pesticides and their misapplication.

Personal Health and Safety

The potential exposure of applicators and workers to pesticides and pesticide residues in greenhouses requires a critical evaluation of frequency of use and pesticide safety during application.

Monitoring

Careful monitoring provides reliable information to guide an integrated pest management program. The most important components of monitoring are sticky traps and crop inspection.

Sticky Traps

The most common greenhouse monitoring technique is using yellow sticky traps (cards or tape) to collect many species of flying insects. These are especially good for adult whiteflies, thrips, leaf miners, fungus gnats, and winged aphids. Note that blue sticky traps are especially attractive to western flower thrips. However, if a wide pest complex is present, use yellow traps.

When using sticky cards, it is important to provide adequate coverage. To do this, use a distribution rate of one card every 100–200 m^2. Increase or decrease the rate depending on the size of the operation being monitored, time of year, and practical aspects of regular monitoring. Change traps before too many insects make maintaining a weekly record difficult.

Crop Inspection

Another important, and often overlooked, monitoring technique is crop inspection. It is essential for monitoring the presence of plant diseases, or of mites, wingless aphids, or the immature stages of whitefly and leaf miner. Adopt a regular sampling pattern that provides good coverage of the whole greenhouse, including entry points and areas of concern. Again, weekly records are necessary.

Early detection of diseases and sedentary pests (such as aphids or mites) makes control easier and may permit management of a problem with only a spot spray.

For successful monitoring, it is necessary to record regularly:

- the date
- crop species and cultivar
- pests identified
- location in the greenhouse
- number of insects trapped
- stage of development (e.g., adults, pupae)
- diseases present or suspected
- control action (pesticide used, rate, area treated, time taken, etc.)

Cultural Controls

Sanitation

Sanitation is the first step in any pest control program. If, due to poor hygiene, a source of infection or infestation is constantly present, pest control programs will be expensive and frustrating. Ensure good sanitation practices in the greenhouse and adjoining structures (boiler rooms, etc.), in the immediate vicinity of the greenhouse, and during every stage of crop production.

Proper greenhouse sanitation is a continual, year-round process. Cleanliness on its own may not control pest problems but it is a basic component of any control program. It is important to:

- remove dead and dying leaves and flowers
- take crop residues far away to be destroyed or composted, and downwind from the greenhouse
- preferably burn residues in accordance with local bylaws or, alternatively, contain and dispose of them
- remove all weeds from inside and immediately outside the greenhouse
- keep walkways clean
- check carefully for pest infestations when bringing new plants into the greenhouse
- avoid overwintering garden or house plants in the greenhouse, otherwise pests will be maintained for an early invasion of the next crop
- maintain good drainage to eliminate puddles and wet surfaces, as these provide ideal breeding sites for fungus gnats and shoreflies, and are a possible source of infection for diseases
- use a heat treatment to remove pest infestations when the greenhouse is empty between crops. Maintain temperatures at >40° C and humidity at <50% for 3–4 days to control insect and mite pests. This is particularly suitable during the warmer months when these temperatures can be achieved by just closing the vents. ***Note: At higher temperatures, plastic fittings may warp.***
- prevent disease organisms from carrying over on empty structures, heating pipes, walks, benches, or equipment, spray with one of these options:
  - — a 0.5%–1% final solution of sodium hypochlorite (bleach). Mix 1 part common household bleach with 9 parts water
  - — Floralife D.C.D., or Chemprocide (quaternary ammonium compound) with fungicidal and bactericidal activity
  - — Virkon, a disinfectant with fungicidal, bactericidal, and virucidal activity
- See also OMAFRA Factsheet, *Sanitation Recommendations for Management of Insect and Mite Pests of Greenhouse Vegetables*, Order No. 94-029.

Environmental Control

Environmental factors such as light, temperature, humidity, water, and nutrients can affect not only the plants, but also the pests and diseases that afflict them. Due to the simultaneous effect environment has on crop production, using environmental control to manage pests is a complex process. Each case is different and needs to be looked at carefully. For example, humidity can play an important role in pest and disease development.

- Spider mites prefer hot, dry conditions. Increasing the humidity by using overhead misting can help retard the development of this pest.

- During the winter months, thrips are not particularly mobile. This is probably due to low light levels rather than to low temperatures and it can have implications for monitoring programs. At these times of the year, yellow sticky cards may not catch thrips, even when they are present and actively feeding in the crop.

- Air moisture affects the development of diseases such as powdery mildew and Botrytis. This means these problems can be improved using environmental controls.

Weed Control Methods

Control of weeds inside and outside the greenhouse is an important part of any pest management program. Weeds can provide a refuge for insect pests and act as a reservoir for diseases. A 10-m strip of carefully maintained lawn around and between greenhouses will also decrease the danger of invasion by insects and diseases from outside. Use fescue grasses for lawn plantings around the greenhouse as they are the least preferred grasses of western flower thrips.

Herbicide application, cultivation, and hand weeding are the most practical methods of controlling weeds in and around greenhouses. However, other, less labour intensive methods include steaming and soil fumigation.

There are no herbicides registered for use in greenhouses.

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Herbicides

OMAFRA Publication 75, *Guide to Weed Control*, contains information on herbicides registered for use in Ontario. Treatments listed in the publication are subject to extensive field trials and observation on farms. Herbicides may be particularly useful for weed control outside.

There is potential for crop damage if any herbicide is used incorrectly. Take the following precautions to minimize spray drift into the greenhouse:

- **Turn off fans to avoid drawing herbicides into the greenhouse**.

- **Close vents before spraying**. Only spray very early in the day to prevent greenhouse temperatures from rising excessively. Delay opening of the vents for at least 30–60 minutes after spraying is completed.

- **Apply herbicides only when wind speed is below 11 kph**. High winds will increase spray drift causing droplets to be carried further away, thereby increasing the chance of drift entering the greenhouse.

- **Use nozzles that minimize spray drift**.

- **Use a sprayer equipped with spray guards**. Guards attached to the nozzle will minimize spray drift and direct sprays to the target.

- **Set sprayer to increase droplet size**. A smaller droplet size will increase spray drift so increasing the size and/or decreasing sprayer pressure will decrease spray drift.

- **If possible, use wipe-on applications**. Drift is minimized and eliminated when this technique is used.

- **Maintain a weed-free environment**. Maintain a 10 metre strip of weed-free, short-cropped lawn around the greenhouse to avoid or minimize use of herbicides. Alternative ground covers are landscape mulch and asphalt.

Read the information on chemicals, safety precautions, calibrations, and care and use of sprayers. Where unwanted herbicide residues remain in soil, apply activated charcoal to reduce the problem. The rate varies depending on the type of chemical contaminant and its concentration. A usual range is 0.5–1.5 kg/100 m^2.

See Chapter 1 for more detailed information on precautions with pesticide use.

Resistant Cultivars

Many commercially available cultivars are resistant to diseases. For example, many tomato cultivars are resistant to Fusarium crown and root rot, and several other fungal and viral diseases. Several cucumber cultivars exist with different degrees of tolerance to powdery mildew. To date, no commercial cultivars are resistant to insect and mite pests.

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Physical Control

Screening

Screens over vents can greatly reduce the influx of insect pests from outside. In warmer climates where pests occur outside all year, screening is an established part of IPM programs. While not as common in temperate areas, screening is becoming more accepted and its value more apparent.

Screening removes an important variable from a grower's pest management program — the movement of pests into the greenhouse from outside. This includes common greenhouse pests such as thrips, aphids, and whiteflies, but also some less common pests such as tarnished plant bug and European corn borer. These can be major pest problems when pesticide use is reduced (e.g. in biological control programs).

Benefits of using insect screening have been demonstrated in Israel and California. In Ontario, growers who installed screens report reduced numbers of pests, lower pesticide use, and improved effectiveness of pest control (especially biological control) measures.

The most important consideration in screening a greenhouse is to determine which pests need to be excluded and its impact on the venting capacity of the greenhouse. The size of the pest determines the mesh size of the screen needed.

Large mesh sizes of the type normally found in household screens are inadequate for excluding most major greenhouse pests. However, they can be useful in keeping out occasional larger pests such as tarnished plant bug and lepidopteran (moth) pests. For smaller insects such as thrips, screens must be of a very fine mesh for total exclusion.

A major concern with screening is the reduction in air flow. Even larger mesh sizes can significantly reduce air movement into the greenhouse.

Increase the intake vent surface area to compensate for the decreased airflow. Forced ventilation/wall vents are much easier and less expensive to screen than top vents. When there are multiple pests of concern choose the mesh size to exclude the smallest of these pests.

Reduced air flow can lead to overheating of the greenhouse, and stress on the fans (in the case of fan-ventilated greenhouses) which have to work harder to pull the same amount of air through the partially-blocked vent. Reduced ventilation can be addressed by increasing the surface area of the screen. In many situations building a screened framework around the vent opening does this. The goal is to ensure that the final surface area of the screens provides sufficient air exchange to allow adequate cooling of the greenhouse.

Several methods are available to determine the increase in surface area of the vents required for any given greenhouse. Important factors are:

- screen mesh size,
- fan capacity, and
- static pressure drop — the difference in air pressure between inside and outside the greenhouse when the fans are running.

Although software programs exist to help with these calculations, they can be complicated and are generally best left to the screening manufacturers.

The small pore size means that screens are very prone to blockage with dust and other deposits, especially in the summer. Such blockage reduces air flow through the screens and may contribute to excessively high temperature conditions. It is important to:

- clean screens regularly
- make sure easy access for cleaning is incorporated in their design.

Wash screens from the inside with a high-pressure hose. Do not do this when the fans are operating. The water will block the pore openings and completely stop air flow, leading to overheating of the greenhouse.

The effectiveness of the screens depends on their ability to exclude flying insects. Repair tears or holes as soon as possible. Small tears can be simply repaired by gluing a piece of screening over the hole.

The cost of screening depends on several factors:

- the final screening design;
- the increase in surface area needed to maintain adequate ventilation;
- the cost of the screening material;
- whether roof vents or side vents are to be screened;
- the frequency of replacement, frequency of cleaning, etc.

For further information, see OMAFRA Factsheet *Screening of Greenhouses for Insect Exclusion,* Order No. 00-021.

Other Physical Controls

Yellow Sticky Tape

Yellow sticky tape can provide useful additional control of flying insect pests. It works on the same principle as the sticky cards used for monitoring. Place the tape along beds or benches, or hang vertically within the crop.

Light Traps

Light traps also provide an easy-to-use, non-pesticide alternative tool for reducing and suppressing moth pests such as adults of tomato pinworm and cabbage loopers. Light traps use a combination of black light lamps for attracting insects, and a low voltage electrocutor that surrounds the lamps. These lamps emit long wave ultraviolet (UV) radiation around 365 nanometres (nm). They also emit some visible light of wavelengths around 430 and 540 nm. Ultraviolet light is the most effective part of the light spectrum for attracting night-flying insects, hence their use for attracting nocturnal moths.

Factors to consider with light traps

- **Size:** The size of the traps affects their attractive powers. Most traps have an attracting diameter range of 40–50 metres. Larger ones are more expensive.

- **Location:** Ideally, place traps in locations best suited to their attracting range. However, convenience tends to dictate their location and most growers usually place them along walkways. In either case:
  - — put a receptacle containing soapy water, or a large sticky board below the trap to catch the victims
  - — place traps high enough so the light emitted from the trap is not blocked by plants, and access by smaller moths is not hindered
  - — place just above the plant canopy.

- **Modification of traps**: Increase the trap's efficiency by removing the metallic grid that surrounds the light and electrocution mechanism. Although the grid size is usually large enough to allow small moths such as tomato pinworm adults to fly through, they definitely impede access by larger moths, such as adults of loopers and tomato fruitworms.

- **Time of year**: Light traps are best used during the cooler months of the year when outdoor temperatures are 10°C and less. This eliminates the problem of attracting more flying pests into the greenhouse. However, during the warmer months, place the traps outside of the greenhouse, at a safe distance, to attract adults away from the greenhouse.

- **Maintenance:** To maintain efficiency, inspect and clean the light traps regularly.

Bumblebees

Light traps attract and kill bumblebees. To avoid or minimize trapping of bees in these traps, use a timer so the lights are on at dusk and off at sunrise. Some beneficials may be attracted to the lights. However, lower night temperatures should reduce activity of most of the beneficials at this time, and therefore, reduce the chances of trapping. Many moth pests, on the other hand, tend to be more active at nights.

Using light traps during the cooler months of the year is a good non-chemical strategy for managing moth pests.

Biological Control

Biological control (biocontrol) is the use of living organisms (such as insects, mites, fungi and bacteria) to control pests such as insects, mites and diseases. Biological control involves more than the release of parasites or predators. A successful program requires planning in advance by at least several months. Consider the following before using biological control.

- Develop a list of resources to help with the program (this may include producers/suppliers of biocontrol agents, other growers, extension specialists, researchers, consultants). Attend courses, seminars, workshops, read magazines and newsletters, and use the Internet to find out as much as possible about biocontrol. Determine what pests need to be controlled and which are the most appropriate natural enemies to use. [See Table 11-1, page 81, for a list of biocontrol agents for principal greenhouse pests.]

- If possible, start in a small isolated greenhouse. This allows beginners to focus on one small area and to become more comfortable with using biological control. Subsequently the program may be expanded to include the entire greenhouse operation, thus minimizing chances of economic failure.

- If possible, screen the area to be used. Movement into the greenhouse of pests from outside is unpredictable from year to year, but can swamp a biocontrol program and make it difficult for the natural enemies to maintain control. (See *Screening*, page 77).
- Ensure all staff are trained to recognize the pests, biocontrol agents, and early symptoms of pest damage.
- Many registered pesticides can have long-term (2–3 months) residual impact against natural enemies. Check the pesticide spray records of the previous several months. If such pesticides have been used, then an appropriate length of time must elapse before starting. Use products with less residual impact to control pests and diseases during this period. Effects of many pesticides are listed in Section 1, page 14, or are available from biocontrol suppliers.
- Check commercial biocontrol agents to evaluate activity and approximate numbers. The quality of natural enemies produced by the major insectaries is usually excellent, but occasionally problems can arise in shipping. The supplier needs to know about any problems in quality in order to identify and correct problems.
- Follow all instructions in storing and releasing the natural enemies. Many can only be stored for a short period of time under fairly specific conditions.
- Monitor populations of pests and natural enemies, and the progress of the biocontrol program by regularly checking for the following:
  — presence of winged biocontrol agents on sticky cards, especially the parasitic wasps. Be aware however, that some (e.g. *Eretmocerus*) are highly attracted to yellow, and too many sticky cards may be detrimental to the program
  — presence of parasitized insects e.g. whiteflies parasitized by *Encarsia* is detected by black scales, and aphids parasitized by *Aphidius* parasitic wasps is detected by mummified aphids
  — presence of non-winged natural enemies by visually inspecting the crop, e.g. predatory mites and immature ladybeetles that do not fly. Inspect the crop, especially in areas of highest pest numbers
  — pest population trends. Monitor pests either on cards or the crop to determine if populations are increasing or decreasing.
- Use compatible pesticides if necessary. Identify such pesticides prior to starting a program so they can be readily used if necessary. See tables in Section 1.
- It is often necessary to be patient and gain some experience to understand a system of biocontrol to become confident in their use.

Commercially–produced biocontrol agents are available for all the major greenhouse insect and mite pests, but not yet for the diseases.

Chemical Control

While pesticides remain an important component of greenhouse pest management programs, monitor their use carefully. For the reasons noted above, make the best use of those available.

Resistance

Resistance can develop to any pesticide used incorrectly or too often. Although there are benefits from new product registrations, do not wait for the latest advance in pesticide chemistry. The long-term problems presented by pesticide resistance far outweigh the short-term gains of a new product if it is used incorrectly.

Resistance is the evolutionary adaptation of a population to survive a pesticide dose that is lethal to most of its individuals. It is an inherited trait, which is passed on to future generations. While resistance does not develop within an individual during its lifetime, it usually exists in a population at very low frequencies (too low to be measured or noticeable). The frequency of resistance increases when pesticide exposure kills susceptible individuals while allowing successively greater numbers of

TABLE 11–1. Biocontrol Agents for Principal Greenhouse Pests

Pests	**Biocontrol Agent**
Whitefly (*Trialeurodes vaporariorum or Bemisia argentifolii*)	*Encarsia formosa* (parasitic wasp)* *Eretmocerus eremicus* (parasitic wasp) *Delphastus pusillus* (predatory beetle)** *Dicyphus hesperus* (predatory bug)
Spider Mite (*Tetranychus urticae*)	*Phytoseiulus persimilis* (predatory mite) *Feltiella acarisuga* (predatory midge) *Stethorus punctillum* (predatory beetle) *Amblyseius californicus* (predatory mite)
Western Flower Thrips (*Frankliniella occidentalis*)	*Amblyseius* spp. (predatory mites) *Orius* spp. (predatory bug) *Hypoaspis* sp. (predatory mite)
Aphids: Various species, especially green peach aphid (*Myzus persicae*) or melon aphid (*Aphis gossypii*)	*Aphidius* spp. (parasitic wasps) *Aphidoletes aphidimyza* (predatory midge) Ladybeetles (*Harmonia* and *Hippodamia*) Lacewings (predators)
Fungus Gnat (*Bradysia* and *Corynoptera* spp.)	*Hypoaspis* spp. (predatory mites) Nematodes – *Steinernema* sp. *Bacillus thuringiensis* (bacterium sold as Vectobac)
Caterpillars (cabbage loopers, European corn borers)	*Bacillus thuringiensis* (bacterium sold as Dipel, Foray etc.) *Catesia marginiventris* (parasitic wasp) *Podisus maculiventris* (predatory bug) *Trichogramma spp.* (parasitic wasps)
Leaf Miner (*Liriomyza* spp.)	*Diglyphus* sp. (parasitic wasp) *Dacnusa* sp. (parasitic wasp)

* Parasite: usually requires only one host for completion of development, often killing it by living on or in its body.

** Predator: feeds on its prey (pest) by catching them, but otherwise lives independently of them. It must consume more than one individual to reach maturity.

Caution is required when using pesticides along with biocontrols since most pesticides are harmful to natural enemies. Applying just one harmful pesticide can prevent any further use of biocontrol agents for an extended period of time. See side effects tables in Section 1, Table 1-7 and Table 1-8.

resistant individuals to survive. Because of the immense genetic diversity of arthropod pests, their short life cycles, great reproductive ability, and the relatively closed nature of greenhouse production, greenhouse insect and mite pests have much potential for developing resistance. Relying on chemical control inevitably leads to development of resistant populations.

Resistance management programs aim to reduce the pressure applied to pest populations by pesticides. The best approach is to minimize pesticide use by regarding them as a last resort measure only. An effective approach for reducing the development of resistance is to use biological control as the major strategy and integrate chemical controls only when necessary. Cultural measures such as resistant varieties and sanitation must be used. Where applicable, incorporate physical controls such as insect barriers and traps.

Note that when pesticides are used in an IPM program, the rate at which resistance develops increases if one class of pesticides (e.g., organophosphate, synthetic pyrethoid, carbamate) is used for a prolonged period. To slow the rate of resistance development, it is necessary to rotate pesticide classes every few weeks, or for a period equal to the generation time of the pest being controlled. (See Section 1, Table 1-6)

Everyone in the industry must use pesticides responsibly so that new products do not lose their effectiveness within a year or two of registration.

Pesticide Application

The most common cause of control failure is *not* resistance. Several other factors determine the effectiveness of a particular pesticide application.

- Ensure accurate calculation and measurement of pesticide rates.

- Proper coverage is needed for good pest control. Simple changes such as walking more slowly through the crop, or walking every aisle instead of every other one, significantly improve performance.

- Maintain spray equipment in good condition. Replace spray nozzles regularly. Older nozzles become worn, which can alter spray pattern and droplet size.

- Consider different application technologies. High-volume, low-volume, and electrostatic-spray application all have their place in the greenhouse for appropriate purposes.

- The biggest improvement comes with effective timing and targeting of sprays. A scouting program can provide the information required to decide when, where, and why a pesticide application is needed. Sprays can then be applied where most needed (e.g., as spot sprays), when they will provide optimal control, and directly at the appropriate pest at the correct life stage.

- Pesticide effectiveness varies, often considerably, from greenhouse to greenhouse, depending on factors such as the usage history of a particular product, the method of application, the time of application, and the water quality. Adjust water pH to 5.5–6.0; at pH>7, the pesticide may degrade rapidly.

Pesticide Compatibility

- Before mixing pesticides, read the product labels carefully for compatibility statements or contact the supplier.

- Avoid mixing EC formulations.

- Never mix herbicides with fungicides and insecticides; apply herbicides with spray equipment reserved for herbicide use only.

12. Insect and Mite Pests

Thrips

Description and Life History

Thrips are tiny, slender, agile insects about 1.5–2 mm in length when fully developed. Adults vary in colour from dark brown or black through to yellow or straw brown. Immatures are usually white or yellow with red eyes. Several thrips species are found in the greenhouse, including eastern flower thrips, onion thrips, and western flower thrips (WFT). [***Plate 58***]

All thrips have a similar life cycle. The adult female lays tiny white eggs inside the leaf tissue. The eggs hatch in 5–7 days, and the white larvae emerge to feed on the leaves and petals. They pass through 2 larval stages, a prepupal stage and a pupal stage (on the soil or plant) before becoming adults. Adults can live up to 7 weeks. A new generation may occur every 20–35 days, depending on the temperature.

Damage

Piercing/sucking mouthparts cause white streaked areas on leaves and fruits or translucent spots on flower petals. Feeding is characterized by tiny, black, fecal deposits on leaf surfaces. Adult females can also damage fruit quality (e.g., of tomatoes) by laying eggs in the fruit. Small whitish "ghost-spots" appear where eggs are laid, which cause uneven fruit ripening. [***Plate 59***]

Thrips also rapidly develop pesticide resistance. They can carry impatiens necrotic spot virus/tomato spotted wilt virus (INSV/TSWV), which can devastate many common greenhouse crops. [***Plate 60***] Proper diagnosis is essential, as these viruses have a wide host range and produce a wide variety of symptoms. Control of INSV/TSWV is difficult, involving thrips population management, removal of infected plants, and good weed control. Use of indicator plants such as petunia or fava bean can be a useful means for early detection of INSV/TSWV.

Control Strategies

Control should employ a good monitoring program using yellow or blue (both very attractive colours to WFT) sticky cards and regular crop inspection.

All stages of the thrips (except eggs) can be detected by tapping buds or flowers over a sheet of white paper.

Biological Control

- Four biological control agents are available for thrips control: the predatory mites *Amblyseius cucumeris, Amblyseius degenerans,* and *Hypoaspis,* and the predatory bug *Orius insidiosus.*
- Best control is obtained by using more than one in combination. Introduce biocontrols when pest levels are low, using a sufficient quantity to achieve success.

***Amblyseius cucumeris* —**

- This buff-coloured predator feeds mainly on the first nymphal stage of thrips.

- *Amblyseius cucumeris* is usually shipped to growers in a mixture that includes bran and bran mites. The bran provides food for the bran mites, which are themselves food for the predatory mites. The bran/mite mixture is available in small sachets or in containers from which the mixture is sprinkled directly onto the crop. The sachets serve as small rearing units from which predatory mites emerge over several weeks.
- Always examine the bran mixture prior to use. The bran should not be mouldy or smell of ammonia, and live predatory and bran mites should be visible.
- Healthy predatory mites move rapidly, whereas bran mites move more slowly. Hang sachets in sheltered positions to minimize dehydration of the bag contents. Rates of application of this predator vary with crop and level of thrips infestation. Contact biological control supplier for suggested rates.

***Amblyseius degenerans* —**

- This predator differs from *A. cucumeris* in appearance and in being able to tolerate less humid conditions.
- It is dark, very agile, and reproduces very well on pollen.
- It can be reared on Castor bean plants, which may be used as release points for the predator within the greenhouse.
- It performs best in situations where it has a pollen source to encourage establishment (e.g. greenhouse peppers).

***Hypoaspis* —**

- This soil-dwelling mite provides additional thrips control by feeding on pupae in the crop media. For more details, see Fungus gnats, page 94.

***Orius insidiosus* —**

- *Orius insidiosus*, the minute pirate bug, is a winged predator that consumes all mobile stages of thrips. Adults are black with white and cream markings on the wings. The youngest nymphs are yellow, while the oldest ones are a dark, mahogany brown.
- *Orius* also feeds on pollen, spider mites, aphids, whiteflies, moth eggs, and young caterpillars. However, its preferred food source is thrips.
- Pirate bugs are sensitive to day length and should not be released in greenhouses before mid-March unless one can provide at least 13 hrs of light.

Chemical Control

Chemical control of WFT can be difficult because they tolerate most pesticides and feed deep within the flower or on developing leaves. This makes them a difficult target for insecticides, so thorough coverage is essential. General recommendations regarding pesticide use for thrips control are as follows:

- To reduce populations, spray 4–5 days apart for three consecutive applications.
- If available, rotate chemical classes and use a single chemical class only for the duration of the thrips' life cycle. This generally means using a different class every 2–3 weeks depending on time of year. Generation times are longer at cooler temperatures.
- It is best to apply pesticides in early morning and late afternoon, when flight activity of thrips is at a peak. This increases exposure of the thrips to the pesticides.

Whiteflies

Description and Life History

Adult whiteflies are small, winged, white insects about 1.5–2 mm long. They lay eggs on the underside of the youngest leaves, and are too small to be seen clearly without a microscope. A female whitefly may lay up to 300 eggs during her lifetime, and can live up to 2 months. The nymphs or crawlers hatch in 5–10 days, are flat and scale-like, and crawl around for a short while before becoming immobile.

Adults emerge after 3 nymphal stages and 1 pupal stage. Old pupal skins and adults may be found on the underside of lower leaves, which may have symptoms of wilt. On average, the whitefly completes its life cycle in 35 days at 18°C and in 18 days at 30°C. Whiteflies have no special overwintering stage and can usually survive as long as some kind of plant life is around. [***Plate 61***]

Species of Whiteflies

Two whiteflies concern growers in Ontario: the greenhouse whitefly (GWF) and the silverleaf whitefly (SLWF). The GWF and SLWF adults look very similar, albeit with some differences:

- The SLWF is slightly smaller than GWF, and its body is more yellow.
- At rest, SLWF holds its wings tent-like above its body, while the GWF holds them flatter and more parallel to the surface on which it is resting.
- The major diagnostic differences between GWF and SLWF appear in the pupal stages. The GWF pupa is raised off the leaf surface and is surrounded by a fringe of hairs, while the SLWF pupa sits flat on the leaf and does not have a fringe. These features are best seen with a microscope.
- SLWF fly in a more direct manner, while the GWF assume a more haphazard flight pattern.
- The life cycle of SLWF takes longer to complete.
- SLWF is less adapted to cold conditions.

Damage

- Piercing/sucking mouthparts allow them to remove sap from the plant, reducing plant vigour.
- Whiteflies excrete large amounts of a sugary substance called honeydew. Honeydew promotes the growth of a black sooty mould fungus on leaf and fruit surfaces, reducing photosynthesis and fruit quality respectively. The sooty mould itself does not damage the plants.
- Whiteflies can transmit viruses. For example, the SLWF is reported to transmit over 60 viruses, and the GWF has been associated with the spread of beet pseudo-yellows virus in cucumbers.

Control Strategies

- Implement a routine monitoring program using yellow sticky cards and plant inspections.
- Use host plants more attractive to whiteflies than the main crop as an early detection tool or as a trap plant. Plant species such as eggplant and fuchsia can be used for these purposes.
- Identify the whitefly species present on the crop.
- React promptly to the presence of whitefly adults either on cards or on terminal leaves.
- Maintain good weed control.

Biological Control

- Two parasitic wasps are commercially available for whitefly control: *Encarsia formosa* and *Eretmocerus eremicus*. *Encarsia formosa* is more effective against GWF, but provides some control against SLWF. *Eretmocerus* is more effective against SLWF, but also provides good control of GWF. Two predators are also available commercially, a small, black beetle, *Delphastus pusillus*, and a predatory bug, *Dicyphus hesperus*.
- Good sanitation, weed control, and low whitefly numbers to begin with, are essential for successful biological control of whitefly.

***Encarsia formosa* —**

Adult wasps about 0.6 mm long, kill whiteflies mainly by laying eggs into the immature stages or scales. Adult *Encarsia* can live for a few days to a month depending on the temperature. Females lay 50–350 eggs in their lifetime. A greenhouse whitefly scale turns black 10–14 days after being parasitized. On average, the adult wasp emerges 2 weeks later. When the adult develops fully, it cuts an opening in the top portion of the black scale before emerging. Parasitized SLWF turn tan–brown and are less easily noticed. For biological control of SLWF, consider higher introduction rates. To use *Encarsia* successfully:

- avoid pesticides with long residual effects for at least 3 months before the initial release
- monitor the crop for whitefly presence at all production stages and follow population level trends. This permits you to place and time parasite releases more accurately
- introduce *Encarsia* at first sign of whitefly, or preventively before whiteflies are detected. If whiteflies are present before you release *Encarsia*, knock back populations with a low-residual pesticide
- avoid using *Encarsia* between December–February without adjusting light and temperature conditions to suit the parasitoid
- distribute *Encarsia* in shaded parts of the plant where the parasites are protected from direct sunlight
- distribute cards relatively evenly, but place more in areas where whiteflies have been observed. You can achieve more distribution points by purchasing cards with fewer parasitized scales per card
- do not remove leaves with immature parasitized scales during deleafing or pruning operations in vegetable crops such as tomato. Such removal slows build-up of *Encarsia* numbers and parasitism rate
- continue introducing *Encarsia* until at least about 80% of the scales on older leaves are black. During warmer months when whiteflies migrate into the greenhouses, you may need to maintain or increase introductions

***Eretmocerus eremicus* —**

Adults are about 0.6 mm long and yellow. They lay eggs under the whitefly larvae (preferably 2nd or 3rd stage). This wasp has a sex ratio of 1:1 (male:female). Introduction rates refer to the number of *females* introduced. This is different from *Encarsia*, where all individuals are female. Like *Encarsia*, mortality of whiteflies can be caused by parasitism and by host feeding. The parasitized whitefly pupa is a yellowish-brownish colour (both GWF and SLWF).

***Delphastus pusillus* —**

Delphastus is a predatory beetle. Both adult and larval *Delphastus* feed on whiteflies, particularly on the eggs and nymphs. *Delphastus* are reported to avoid parasitized scales, feeding on principally the non-parasitized scales. This behaviour makes *Delphastus* compatible with *Encarsia*. Use these beetles to supplement the activity of *Encarsia* in reducing whitefly populations. Adult *Delphastus* live for 6–9 weeks. They are reported to require a minimum diet of 10 whitefly eggs/day to reproduce. These beetles are reported to work well on cucumber but not tomato crops.

***Dicyphus hesperus* —**

Dicyphus is a predatory bug with piercing/sucking mouth-parts. These bugs are general feeders but they appear to have a preference for whiteflies, feeding particularly on the eggs and larval stages. To a lesser extent, they will feed on aphids, spider mites, thrips, leafminer larvae, and moth eggs. In the absence of prey, a high population of *Dicyphus* may cause damage to tomato fruits. For management of whiteflies, it is best to use *Dicyphus* in conjunction with the parasitic wasps, *Encarsia formosa* and *Eretmocerus eremicus*.

Physical Control

***Sticky Traps* —**

Use yellow sticky traps in various forms to trap large numbers of adult whiteflies. Large, yellow sticky boards or 30 cm yellow sticky tapes can be placed in "hot spots" at a rate of about 1/plant. Alternatively, hang yellow, sticky tape between posts along plant rows. Such tapes will also trap fungus gnats, shoreflies, *Aphidius* spp., and *Encarsia,* especially under low whitefly populations. Be careful in using large quantities of sticky tape in conjunction with parasitoids, especially with *Eretmocerus* which is highly attracted to the colour yellow.

***Vacuuming* —**

Hand vacuuming of adults in "hot-spots" is a very effective way to rapidly remove adult whiteflies.

***Insect barriers* —**

Installing fine screens over vents and doorways will significantly reduce movement of outdoor populations into greenhouses. Where whiteflies move in from adjacent field crops (e.g. field tomatoes) in large numbers at certain times of the year (e.g. during harvest), consider screening as a first line of defence.

Chemical Control

- Whiteflies have developed resistance to many pesticides. Judicious use will extend the effective life of pesticides while delaying the build-up of resistance.
- Rational and judicious pesticide use requires a regular monitoring program, using action thresholds, rotating chemical classes, and incorporating the use of all available non-chemical control strategies.
- When using a systemic insecticide, ensure that it is applied correctly. The root system should be well developed and the plant actively growing. Limited watering 12–18 hr before application assists in better uptake and effectiveness.

Two-Spotted Spider Mite

Description and Life History

The two-spotted spider mite (TSSM) attacks many greenhouse crops. The 8-legged female adult is approximately 0.5 mm long with a rounded abdomen. The male is distinguished from the female by its smaller, narrower body and pointed abdomen. Adults range from pale yellow to orange to brown. The overwintering or diapausing stage is reddish orange. Day lengths of 12hrs and less, decreasing temperatures, and a deteriorating food source will induce diapause in spider mites. During diapause, spider mites can tolerate very low temperatures. A short spell of heating is not sufficient to break its diapause.

Close examination of leaf undersurfaces shows mites to be very tiny moving dots. The 2 dark spots on the body of TSSM are the gut contents showing through the transparent body. After mating, each female mite lays about 6 pearly-white eggs/day. Over an average lifetime, a female lays 100 or more eggs on the undersurface of foliage. Newly hatched mites pass through the typical 6-legged larval stage and 8–legged protonymph and deutonymph stages. The last of these is an immobile resting stage, hence a very difficult target for miticides. The life cycle from egg–adult ranges from 23 days at 15°C to just 4 days at 32°C. Development is fastest under hot, dry conditions. [***Plate 62***]

Damage

- All active stages of the two-spotted spider mite feed by piercing the lower epidermis of the leaf with sucking mouthparts.
- The feeding injury starts as a yellow "stippling." As mite numbers increase, the entire leaf appears stippled or light-coloured on the upper surface. Very heavily infested leaves become yellow and brittle, with obvious webbing on the leaves.
- If infestations proceed without control measures, plants may be killed. Mite populations seem to explode at certain times of the year, since the life cycle varies considerably with temperature.
- Other factors, such as humidity and plant nutrition are important, and can be used to help reduce mite outbreaks.

Control Strategies

Conduct a proper cleanup between crops to reduce initial infestations in subsequent crops. Do this just before the overwintering or diapausing phase of the spider mites, because the diapausing mites hibernate in the ground, hollow stems, pipefittings, cracks, and crevices during the fall and winter months. The mites become active again during late winter and early spring. The red mite stages are generally pesticide-resistant and are not as readily fed upon by predators. When the red post-diapausing mites are detected, use low residual sprays on lightly infested leaves, and remove and destroy more heavily infested leaves.

Biological Control

- The principal biological control agent available for spider mites is the predatory mite, *Phytoseiulus persimilis.*
- Other biological control agents include the predatory mite, *Amblyseius californicus*, a ladybeetle, *Stethorus punctillum*, and the predatory mosquito-like midge, *Feltiella acarisuga*.

***Phytoseiulus persimilis* —**

- *Phytoseiulus persimilis* is about the same size as TSSM, but is pear-shaped, pale salmon to bright orange, does not have the 2 spots, and moves more rapidly on long legs. It feeds specifically on spider mite and does not hibernate.

- Without spider mites, the predators die, and new introductions are required. Adult predators feed on about 7 adults or 15–20 eggs per day. At 20°C, *P. persimilis* almost doubles the reproductive rate of the pest. Control with *P. persimilis* is best between 20°C –26°C. Above 30°C and at humidities under 60%, predators do not thrive, and seek cooler, more protected areas lower down in the crop canopy. In contrast, TSSM thrive under these conditions. Predators are available commercially either mixed with vermiculite or on bean leaves. With either carrier, treat infested plants at first sign of damage. Before releasing the predators, always ensure that they are alive and very active and try to place a few predators onto every infested leaf.

***Amblyseius californicus* —**
This predatory mite is amber-coloured and droplet shaped, very similar in appearance to *A. cucumeris*. Like *A. cucumeris*, it attaches whitish oval eggs to hairs along the veins of the undersides of leaves. It can feed on other mites such as the carmine spider mite, and can survive on pollen. It is also reported to tolerate high temperatures, low humidities and a range of pesticides.

***Stethorus punctillum* —**
This is a tiny, oval, convex, shiny black ladybeetle. It lays white eggs singly on the undersides of leaves. The eggs turn blackish just before the larvae hatch. Newly-hatched larvae are grey to blackish and have many long branched hairs. Just prior to pupation, the entire larva turns reddish. Pupae are black and flattened, and the entire body is covered with yellow hairs. Newly emerged adults are reddish-orange for a few hours and then turn black. *Stethorus punctillum* is strictly a predator of plant-feeding mites and prefers the egg stage. It is reported to establish on pepper and cucumber crops, but not on tomato crops.

***Feltiella acarisuga* —**
Feltiella acarisuga, also known as *Therodiplosis persicae*, is a predatory midge that resembles mosquitoes. The adult is able to fly and actively search for spider mites. It lays eggs alongside spider mite colonies. Orange-coloured larvae hatch from the eggs and can feed on all stages of spider mites. Larvae pupate next to the leaf veins in white cocoons. The life cycle varies with temperature, taking 2–4 weeks to complete. *Feltiella* will feed on red diapausing mites on which *Phytoseiulus* will only reluctantly feed. Establishment, though variable, has been reported to occur on all greenhouse crops including tomato under suitable conditions. *Feltiella* performs best under high humidity (>80% RH) conditions and in 'hot spots'. Note that use of sulphur can reduce the efficacy and survival of *Feltiella*.

Physical Control

Misting plants and maintaining relatively high humidities help suppress spider mite populations. For example, at 20°C and 36% RH, female TSSM will lay about 7 eggs per day; at 95% humidity, about 30% fewer eggs are laid.

Chemical Control

Because of their great reproductive potential, two-spotted spider mites easily develop pesticide resistance. To effectively manage this pest using pesticides, observe these guidelines:

- Direct sprays to the underside of leaves where spider mites usually congregate.
- The webs in areas of high mite density can protect the mites and the eggs within and beneath the web. In such cases, use higher spray pressures to penetrate the web.
- Because of TSSM's high reproductive potential, use non-chemical control options as much as possible to minimize the development of pesticide resistance.

Aphids

Description and Life History

Aphids are small (2–3 mm), soft-bodied insects with long legs and antennae. A pair of tube-like structures called cornicles project from the posterior end. Several species may infest greenhouses, with colour patterns ranging between black, grey, red, yellow, and green. The species most commonly found in greenhouse crops are the green peach aphid *(Myzus persicae)*, the cotton or melon aphid *(Aphis gossypii)*, and the potato aphid *(Macrosiphum euphorbiae)*. Another species that can be found causing leaf distortion in pepper crops is the glasshouse potato aphid (*Aulacorthum solani*). [***Plate 63***]

Adult aphids are predominantly wingless, although winged adults can develop under conditions of high population density. This adaptation serves as a dispersal mechanism, allowing aphids to move into a greenhouse from outside, or to spread rapidly within a greenhouse.

In a greenhouse situation, all aphids are female and give birth to live young. These offspring can reproduce within 7–10 days. One aphid can give birth to 60–100 young over a 20–day period. Aphids can rapidly achieve very large populations.

Damage

- Aphids pierce plant tissue with their mouthparts and suck out the sap, causing deformed leaves and flowers.
- Aphids moult through a number of different stages before they become adults. The cast-off skins they leave behind each time they moult are a visible sign of their presence.
- They excrete a sugary, sticky substance called honeydew, which promotes the development of black, sooty mould fungus.
- Some aphids can transmit plant virus diseases, such as cucumber mosaic virus in cucumber crops.

Control Strategies

- When monitoring for aphids, check for winged adults on yellow sticky boards.
- For wingless aphids, it is necessary to inspect new foliage carefully and regularly to prevent large infestations.
- Spot-treating isolated infestations can prevent their spread to the rest of the greenhouse.
- When infestations occur in the blossom stage, smokes may be more effective and less phytotoxic to plants.

Biological Control

- Several types of biological control agents are readily available: the predatory midge *Aphidoletes aphidimyza*, the parasitic wasp *Aphidius* spp., and ladybeetles or ladybugs (*Hippodamia convergens* and *Harmonia axyridis*).
- *Aphidoletes* and ladybeetles are usually used to supplement the activity of *Aphidius* and for reducing aphid populations in “hot spot” areas.

Aphidoletes aphidimyza —

- In the adult stage, *A. aphidimyza* resemble small mosquitoes or fungus gnats. Females lay up to 200 eggs in their lifetime. Eggs are laid close to aphid colonies, so the orange-coloured larvae have a readily available food source on hatching.

- Eggs usually hatch after 2–3 days. After 7–14 days in the larval stage, they drop to the floor to pupate. The pupal stage usually lasts about 2 weeks. Adult *A. aphidimyza* feed on honeydew, and larvae can kill 3–50 aphids per day. Under natural day lengths, *A. aphidimyza* enters diapause between September and March — they are not effective during this period.

***Aphidius spp.* —**

- This parasitic wasp does not enter diapause and is usually more effective during winter, early spring, and fall. During summer, other parasitic wasp species can parasitize *Aphidius* reducing their impact on aphid populations. Optimum conditions for *Aphidius* are 18°C –25°C and 80% RH. *Aphidius* completes its development from egg to adult in about 10 days at 25°C, and 14 days at 21°C.
- Several species of *Aphidius* are commercially available. *Aphidius matricariae* can parasitize about 40 aphid species, including the green peach aphid, while *Aphidius colemani* is more effective against the cotton aphid, but still works quite effectively against the green peach aphid. *Aphidius ervi* is the best choice against the potato aphid.

***Hippodamia convergens* —**

- Both adult and larval ladybeetles feed on aphids. Larvae can feed on a total of about 400 aphids, and adults on up to 5,000 aphids each. Ladybeetles enter diapause under short-day conditions. When day lengths are suitable, ladybeetles must feed on aphids to maintain egg production. Eggs are torpedo-shaped and orange-coloured. They are laid in circular clusters on the underside of leaves, and hatch in 2–5 days.
- The larval stage lasts for about 3 weeks, after which they pupate. Adults emerge from pupal cases after 3–5 days. To increase the percentage of ladybeetles remaining in the greenhouse, release them in late evening and sprinkle a sweet liquid (e.g., diluted pop) over the beetles. The sweet liquid provides an immediate energy and water source.

***Harmonia axyridis* —**

- This ladybeetle is also known as the multi–coloured Asian ladybeetle, Asian ladybeetle, Japanese ladybeetle, or Halloween ladybeetle. Adults are oval, convex, about 6 mm long, and occur in many colour forms. They are most commonly orange with black spots, or they may be black with red spots. Eggs are yellow and laid in clusters underneath leaves. The larvae are usually blackish with bright yellow spots along their sides. Total time for development from egg to adult at 25°C is 16–20 days. Females live 2–3 months and lay several hundred eggs each during their lifetime. Adults and larvae are voracious feeders and are reported to consume approximately 50–100 aphids per day.

Cabbage Loopers

Description and Life History

Cabbage loopers are pale green caterpillars with several wavy white lines along the length of the body. Loopers can be up to 4 cm in length and characteristically move by forming a loop with their bodies. Tiny loopers hatch from pinhead-sized pearly white, round eggs which are usually laid on the undersides of leaves. Loopers feed mainly on the undersides of leaves and excrete dark green frass (droppings) in the vicinity of the feeding area. This feeding or caterpillar larval stage lasts about 2 weeks, after which the mature larva pupates inside a webbed cocoon attached to the undersides of a leaf. The pupa is light green at first, becoming increasingly darker as it matures. Pupation can also take place under ground plastic, or in the ground along side-walls. The adult emerges in about 2 weeks and is greyish brown with a silvery spot resembling the figure eight on the middle of each front wing. The life cycle is completed in about 28 days.

Generally, cabbage loopers are not able to overwinter in Canada and infestations start each year with the arrival of adults from southern USA. However, if conditions are favourable, loopers are able to survive in greenhouses from one season to the next. [***Plate 64***]

Damage

Damage by young loopers consists of small areas on the undersides of leaves that have been superficially chewed and scraped away. As the loopers increase in size, they cut through the plant tissue leaving ragged holes between the leaf veins. The size of the holes is proportional to the maturity of the loopers. These caterpillars can also feed on fruits, but they are more often observed on the foliage. Most of the damage is carried out by the last 2 larval stages.

Control Strategies

Their initial presence can be detected through the use of light or pheromone traps. Light traps are useful during cooler months of the year when the risk of attracting additional moth pests is lessened. Pheromone traps can be used to detect the presence of male moths. Principal control strategies include the following:

- proper sanitation between crops to remove any residual populations, thereby preventing early infestation of the new crop
- using light traps to kill adults
- using insect screens over vents and doorways to prevent entry of adults into the greenhouse
- frequent applications of the bacterial insecticide, *Bacillus thuringiensis* (Dipel, Foray), to target particularly the younger larval stages
- release of biological control agents such as the parasitic wasp, *Trichogramma* spp., that attack the egg stage of the cabbage looper, and another parasitic wasp, *Cotesia marginiventris*, that attacks the larval stage.

Lygus Bugs

Description and Life History

The lygus bug is also commonly known as the tarnished plant bug. The adult is 5–6 mm in length, flat, oval-shaped, greenish brown in colour, with a small Y-shaped yellow mark on its back. The younger stages or the nymphs are light green and resemble aphids except they move swiftly when disturbed. All stages (except eggs) of the lygus bug have stylets used to pierce young or succulent plant parts for extracting juices. They feed on a wide range of plant hosts including most vegetable and fruit crops, and many weeds. Adults usually overwinter in protected areas in plant debris outdoors and emerge from these overwintering sites in early spring to seek out egg-laying sites, such as in greenhouse crops. When they find a suitable plant host (including greenhouse peppers and cucumbers), eggs are inserted into the plant tissue and nymphs hatch out after a few days. They undergo 5 nymphal stages completing their life cycle in about 4 weeks, depending on temperature. There are about 3 generations outdoors in southwestern Ontario, and perhaps a few more in greenhouses. [***Plate 65***]

Damage

Lygus bugs feed on flowers and shoot tips. They cause damage by piercing the tissue and injecting saliva that causes death or distortion of the tissue. Such feeding results in loss of growing points, flower abortion, distortion of new growth as in developing leaves, flowers, and fruits. Loss of growing points characteristically results in development of bushy plants, e.g. in peppers, because of the simultaneous growth of side shoots. Yellow varieties of pepper appear to be particularly attractive to this bug.

Control Strategies

Monitoring for lygus bugs is best done using a combination of yellow sticky cards and crop inspection. Often they may be observed on the cards before they are detected in the crop. The first line of defence is to control weeds in the immediate greenhouse area, starting the previous fall. This discourages nearby overwintering populations that serve as a source of infestation the following spring. Maintain a well-mowed surrounding area. Use coarse insect screens to prevent entry of adult bugs.

Biological Control

Good populations of generalist predators such as *Orius* have been associated with supression of lygus bugs. A parasitic wasp, *Anaphes iole*, attacks only the egg stage and is available for biological control. There are other biological control agents still on trial. These may be available in future for an expanded biological control program for lygus bugs.

Chemical Control

Only one product, Thiodan, is registered for use on greenhouse peppers. As far as possible, use spot treatments to minimize its impact on biological control programs.

European Corn Borer

Description and Life History

The larva is the damaging stage of the European corn borer (ECB). It is grey to tan in colour with dark spots along the back, and with a brownish black head. These caterpillars spend most of their life feeding within its host e.g. pepper fruits. Outdoors, it is the final and fifth larval stage that overwinters in corn debris in fall, and completes development to the adult stage in the following spring. Adults, which are about 1.5–2.0 cm long, light brown with dark wavy bands, search for suitable hosts such as corn and peppers, and lay eggs on the undersides of leaves in a mass of 5–50 eggs which appear as fine fish scales. Egg-laying is favoured by warm, calm evenings and overnight dew. Immediately after hatching, the tiny larvae feed very little or immediately spin a web from which it hangs until it finds a pepper fruit. At that point, the larva bores its way, usually under the calyx, into the fruit and settles down to eating and growing by moulting 5 times. The final larval stage can either pupate within the fruit or bore its way out of the pepper and pupate outside of the fruit. European corn borers normally begin infestations in spring around May to early June. There are 2 generations of this borer in southwestern Ontario, and 1 generation elsewhere in Ontario. [***Plate 66***]

Damage

Of the major greenhouse crops (tomato, cucumber, pepper, lettuce), only pepper is attacked by ECB. Fruits are the target for feeding, whereas damage to leaves is nonexistent or insignificant. The larva bores into the fruit and feeds on the internal portion of the fruit. In addition to the direct feeding damage, the entry holes facilitate eventual rotting and breakdown of the internal tissues of the fruit. Early infestation of pepper fruits may be difficult to detect because the caterpillar inconspicuously bores into the fruit under the calyx. However, their presence is indicated by premature colouring of the fruit, and by the presence of light brown droppings around the entrance hole. For more information on European corn borer, see OMAFRA Factsheet *European Corn Borer in Field Corn,* Order No. 97-021.

Control Strategies

Monitoring and Cultural Control To monitor for ECB in spring, use pheromone and black light traps to detect initial flight of the adults. Light traps attract both males and females; pheromone traps attract only males. However, management of ECB begins with clearing of overwintering sites such as corn fields and grassy areas during the previous fall.

Physical Entry by adults into the greenhouse may be reduced by using coarse screens over vents, doorways and all openings. To attract adults away from the greenhouse, place ultra violet light traps that attract and kill adult ECB, outside the greenhouse at least 10–20 m away. Such traps require a timed power source and regular cleaning of the electrocution mechanism.

Biological The parasitic wasp, *Trichogramma brassicae,* has been used with some success in field corn trials. It is a tiny wasp that attacks only the egg stage and requires even distribution throughout the crop for maximum effectiveness. Its effectiveness in greenhouse peppers still has to be determined.

Fungus Gnats/Shore Flies

Description and Life History

The grey to black adult fungus gnat is about 3–4 mm long with long legs, thread-like antennae, and large compound eyes that meet above the base of the antennae. The adult is a weak flier, frequently observed resting on the media surface. Each female lives about 10 days and lays about 150 oval, white eggs in the organic matter of the media. Eggs hatch in 2–7 days, depending on the temperature, producing white larvae that are 4–6 mm long. [***Plate 67***]

The larvae have 12 abdominal segments and a distinctive shiny black head. The larvae spin pupal cases and remain immobile in the soil for 4–6 days, after which adult flies emerge. As with most insects, fungus gnats become more active and reproduce more quickly at warmer temperatures. The life cycle can be completed in 21 days at 24°C, compared with 38 days at 16°C.

Shoreflies, another common greenhouse pest, are often confused with fungus gnats. The adults are stouter than fungus gnats, stronger fliers, and have 5 clear spots on the wings. The larvae live in soil, like fungus gnats, but lack the distinctive black head capsule. They are likely to prefer moister conditions than fungus gnats and are often found in wet areas under benches with both adults and larvae feeding on algae.

Shoreflies are not usually a threat to greenhouse crops, but can feed on roots in recirculating systems. Shorefly control requires controlling algae, either directly (by applying chemicals) or indirectly (by reducing moisture necessary for algal growth; or reducing the high light levels the algae need).

Damage

- Although fungus gnats generally feed on decaying organic matter in the soil, they can also feed on the young roots of plants. This is especially true when gnat populations are high.

- They have occasionally been observed feeding on the youngest shoots of cucumbers.
- Root feeding by fungus gnats makes a plant susceptible to root diseases such as *Pythium* root rot. Fungus gnats have also been implicated in the spread of disease-causing organisms such as *Pythium, Fusarium, Verticillium,* and *Rhizoctonia.*

Control Strategies

- Sanitation inside the greenhouse and in the surrounding outside area is very important.
- Avoid over-watering and maintain good drainage to prevent water puddling — fungus gnats and shoreflies thrive in moist conditions.

Biological Control

Biological control agents include predatory mites, *Hypoaspis* spp., and a parasitic nematode, *Steinernema feltiae.*

***Hypoaspis* —**

- *Hypoaspis* is a soil-dwelling, brown mite that feeds on fungus gnat eggs and larvae, algae, thrips pupae, springtails, nematodes, and larvae of various flies and beetles. *Hypoaspis* is a hardy mite that can live about 24 days without food. It is not affected by low light conditions and has a life cycle of about 9–11 days under greenhouse conditions.
- *Hypoaspis* is found mainly in the top 1 cm of the growing media. It works best when applied to the media just after plants are potted up or vegetable seedlings planted out. *Hypoaspis* is most effective when fungus gnat populations are still low or non-existent.

***Nematodes* —**

The nematode *Steinernema feltiae* is best used under higher population conditions. Nematodes enter the body openings of fungus gnat larvae, then release bacteria, which multiply and kill the larvae. Because nematodes are believed unable to multiply within the bodies of fungus gnat larvae, use several consecutive nematode applications to achieve control. *To use nematodes successfully:*

- shake nematode stock solutions every hour to incorporate oxygen into the water
- use the solution within 4 hours
- media temperatures should be 16°C–30°C
- never expose nematode suspensions to direct sunlight. This will destroy the bacteria within the bodies of the nematodes
- plant media should be pH 3–8
- check the compatibility or residual activity of fungicides before applying to media that have been, or will be, treated with nematodes.

Leafminers

Description and Life History

Two main species of leafminers are important to Ontario growers: the vegetable leafminer *(Liriomyza sativae)* and the serpentine leafminer *(Liriomyza trifolii).* A third species, the pea leafminer, *Liriomyza huidobrensis*, which is a major pest in other parts of the world, has also been found in Ontario. Although the serpentine leafminer can complete development on tomatoes and cucumbers, it prefers chrysanthemums, gerbera, and gypsophila. Conversely, the vegetable leafminer prefers tomatoes, cucumbers, and celery, but will attack chrysanthemums and other plants in the absence of its preferred host. The pea leafminer has a wider host range and can move into field grown crops as well, including vegetable crops such as cole crops, lettuce and celery. The 3 species of leafminers are similar in appearance and biology.

The adult leafminer is small (approximately 3 mm long), with black and yellow markings on the head and thorax. Adults become active at sunrise. Females feed on soft, succulent leaves by piercing the surface with their ovipositor, then lapping the liquid exuding from the leaf.

Female flies begin laying eggs 12–24 hours after emerging from the pupa. They lay about 250 eggs during their approximately 30-day lifetime. Eggs are laid in about one out of seven leaf punctures (or "stipples"). The optimal temperature for leafminer development is 30°C. At temperatures above or below 30°C, egg production/female declines considerably. After 2–4 days, eggs hatch and the larvae begin feeding (or mining) in the leaf tissue. [***Plate 68***]

The larvae mature in 4–7 days in summer, then cut a hole in the leaf surface and drop to the ground. Pupation takes place within a few hours, in the plant media or on plastic sheeting (where used). Pupation can also occur on the leaves. The pupal stage may last 5–10 days in the summer, and up to 90 days during periods of low temperature (10°C–12°C) and scarce food supply. This may account for the winter survival of leafminers around the inside perimeter of the greenhouse, though no adult leafminers are evident. From the pupae, a new generation of adult flies emerges.

There is considerable overlapping of stages of the insect life cycle within any greenhouse. The complete life cycle of the leafminer can be as short as 14 days at 30°C, 24 days at 20°C, and 65days at 14°C.

Damage

- Leafminer feeding may indirectly affect yield by reducing the plant's photosynthetic area, and by damaging water-conducting vessels (causing leaf desiccation and leaf drop).

Control Strategies

- Inspect all new plant material entering the greenhouse.
- Destroy infested seedlings, cuttings, and plant parts.
- Monitor the crop for pests with yellow sticky boards and regular crop inspections.
- Get rid of weeds inside and outside the greenhouse. Weeds such as lamb's-quarter, chickweed, dandelion, plantain, common mallow, and nightshade are good hosts for leafminers.
- Do not over-fertilize the crop — excess nitrogen levels can increase aphid and leafminer problems.
- Detached leaves should be bagged and removed from the greenhouse as soon as possible. Leafminer larvae can complete their development in leaves even after they are removed from the plant.

Biological Control

Biological control agents include the parasitic wasps, *Diglyphus isaea* and *Dacnusa sibirica*. *Diglyphus* is likely to be a better choice in summer, when its numbers may be supplemented by naturally occurring populations migrating into the greenhouse from outside. *Dacnusa* will perform better than *Diglyphus* over the winter.

***Diglyphus isaea* —**

- *Diglyphus* is a small, black wasp with a metallic, green sheen and short antennae. After locating a mine, the female first paralyzes the leafminer, then inserts an egg through the leaf, placing it near the leafminer. It may deposit up to 5 eggs this way, laying about 60 eggs during its lifetime. The larva that hatches is initially colourless, then becomes yellow brown, and finally turquoise. Development time from egg to adult is about 11 days at 25°C. This is generally shorter than that of both the leafminer and *Dacnusa*.

- *Diglyphus* can parasitize leafminers already parasitized by *Dacnusa*. It becomes the dominant species during summer, when warm conditions favour their activity. Presence of short mines indicates *Diglyphus* activity, as the paralyzed leafminer stops feeding immediately.

***Dacnusa sibirica* —**

- The adult is a small, black wasp that differs from *Diglyphus* in having long, flexible antennae and in lacking the metallic, green sheen. Unlike *Diglyphus*, a female *Dacnusa* inserts an egg into the body of the leafminer. Each female lives for about 2 weeks, during which time she may lay up to 90 eggs.
- Eggs hatch within 4 days, and the larvae mature within the leafminer pupae. Development time from egg to adult is about 2 weeks at 22°C. All *Dacnusa* development takes place within the leafminer's body; therefore, assessing parasitism is difficult.

Occasional Greenhouse Pests

Ants

Ants are easily recognized by their elbowed antennae and narrow waists. They range from 1.5–6 mm long.

Ants are attracted to sweet substances. In greenhouses where insect feeding has produced honeydew, or where flowers have nectaries, ants may be a problem. Treat all ant trails or nests located in or near the greenhouse. Flooding nests with insecticidal soap and using household boric acid baits can provide some control.

Caterpillars

Several different insects have caterpillar stages that damage greenhouse crops. These include leaf rollers, armyworms, cutworms, loopers, fruitworms, hornworms, and leaf tier and stalk borers. The adult moths of these caterpillars are often attracted to greenhouse lights in the summer, and will then lay eggs that hatch into the caterpillar pest.

- Armyworms and cutworms feed directly on plant foliage and may cause considerable damage. Both insects are dark brown or grey with longitudinal stripes. Cutworms burrow into the soil during the day and come out to feed at night.
- Use insecticides recommended for caterpillars to bring armyworm and cutworm infestations under control.
- Stalk borers bore into plant stems, making them more difficult to control.
- Pheromone traps can be used to detect certain moth species, and light traps can be used to monitor many species.
- If these pests are detected early, apply controls immediately afterwards. Screened vents help prevent the entry of all adult stages of the caterpillars, and a good inside/outside weed control program will reduce potential infestation sites. Apply the bacterial insecticide, Dipel or Foray, for good control of loopers and most leaf-eating caterpillars that are not miners.

Grasshoppers

Grasshoppers are easily recognizable and occasionally invade greenhouses.

- They will feed on almost any vegetation and, in large numbers, can destroy plants.
- Grass and weeds near greenhouses may allow a grasshopper infestation to occur, usually in late summer and fall.

Mites

Cyclamen Mite/Broad Mite —

Cyclamen mites and broad mites are microscopic in size. They are no more than 0.25 mm long and cannot be seen without magnification. The hind pair of legs of the female is thread-like while those of the male are pincer-like.

- The pale brown female mite deposits approximately 100 eggs, 80% of them female, around the crown of the plant or along the midrib of unfolded leaves. The mites develop through the 6–legged larval stage and quiescent nymphal stage with 8 legs, similarly to the two-spotted mite. The life cycle from egg to adult is about 2 weeks, but varies depending on the temperature.

- Distorted leaf tissue and/or small, blasted or twisted flower buds and flowers are usually the first damage symptoms. Foliage will often show purplish areas. The cyclamen mites feed around the crowns of plants or in the flower buds. Cyclamen is usually the most seriously injured, but many foliage, bedding plants, other potted crops and peppers can also be attacked.

Tomato Russet Mite —

The adult mite is 0.2 mm long and 0.05 mm wide. Because of its small size, the mite is not noticed on plants until it reaches damaging levels. At this time, the stems, leaves, and fruit appear beige or bronze as a result of the high mite population density. [***Plate 69***]

- Russet mites appear to thrive under dry conditions. The life cycle lasts about 6 days at 27°C and 30% RH. Females can lay about 16 eggs during their lifetime of about 3 weeks. Russet mites feed first on stems, then on leaves.
- Damage symptoms include yellowing, curling, and wilting of leaves, flower abortion, and bronzed, cracked fruit. If not controlled, the tomato russet mite will eventually kill the plant.
- Alternative hosts for this pest include nightshade, petunia, and several other species in the same family as the tomato.
- No early detection techniques exist for this mite. Once established in a crop, they easily spread on hands, equipment, and clothing.
- There are no current recommendations for biological control. Work-to-date indicates that 2 predatory mites, *Amblyseius fallacis* and *Typhlodromus occidentalis*, are potential biocontrol agents.

Slugs and Snails

Slugs are dark grey, soft-bodied creatures, 1.3–10 cm long. They glide over plants leaving a shiny trail. Slugs eat the foliage of most greenhouse plants, shredding the leaves, and they may completely destroy a plant.

Snails are similar in colour and appearance to slugs, except that a snail bears a noticeable shell. The shell varies in colour and markings, and may be 1.3–5 cm in diameter. Snails are particularly injurious to seedlings.

- They eat holes in the flowers and leaves of many plants.
- Individual snails may lay up to 100 eggs, depending on the species. Slugs lay fewer eggs that may remain unhatched for long periods under dry conditions. They hatch upon return of moist conditions.
- Both slugs and snails need a damp environment and fairly humid air to survive. They avoid the sun and come out primarily at night or on cloudy days. During the day, slugs hide under boards and rocks or in other damp, shady places. If the air or substrate is dry, a snail can pull its entire body into its shell and remain dormant for up to 4 years.
- Some growers have reported good control of slugs by using certain parasitic nematodes.

- Indirect control strategies for these organisms should focus on reducing their favoured habitat. These strategies include:
  - — remove boards, bricks, etc. that are in contact with the ground, or arrange these to permit proper air circulation around and under them
  - — maintain a plant density that permits sunshine to penetrate to the ground level, provides good air-circulation, and allows the plant media to dry
  - — where a low plant density is inappropriate, use a ground cover unattractive to snails (e.g., rough cut cedar chips or crushed eggshells)
  - — sawdust and diatomaceous earth are an effective barrier if kept dry.
- Various devices can trap or attract slugs and snails for subsequent destruction.
  - — Traps can be made using beer or a mixture of water and commercial yeast as an attractant.
  - — Inverted flower pots with crushed snails or slugs, or inverted grapefruit halves, are good devices for attracting slugs and snails.
- Chemical controls involve baited pesticides that combine bran bait with metaldehyde.
  - — Metaldehyde is toxic. Do not expose to children and pets.
  - — Prolonged use of baits is likely to produce a local bait-resistant population.

Sowbugs/ Pillbugs

Sowbugs and pillbugs have grey, flattened, oval bodies up to 13 mm long with 7 pairs of legs. Sowbugs have 2 small, tail-like structures that the pillbugs lack.

- They are both small decomposers, but occasionally feed on roots and tender plant parts causing seedling damage. They feed at night and hide during the day, preferring dark, moist areas with abundant organic matter.
- Sterilizing soil and eliminating decaying plant material and moist areas will help prevent a build-up of these pests.
- Many strategies used for snail and slug control also suppress sowbug/pillbug populations.

Springtails

Springtails are tiny, wingless insects 2–6 mm long. They range in colour from white, grey, or yellow, to red, orange, purple, brown, or mottled hues.

- They are usually found on the surface of moist soil, in pots, or within the soil.
- They have a spring-like apparatus at the end of the abdomen that allows them to spring into the air.
- Most springtails are scavengers, feeding on decaying organic matter, algae, or fungi. Because they usually do not feed on living plant material, chemical controls are rarely necessary.

Striped Cucumber Beetles

Striped cucumber beetles are yellow-green beetles about 6 mm long. They have 3 longitudinal stripes. These beetles and a relative, the spotted cucumber beetle, carry the bacteria, *Erwinia tracheiphila,* which causes bacterial wilt in cucumbers and related species such as melons and squash.

- Striped adult cucumber beetles overwinter outdoors under old leaves, old logs, or trash. They emerge the following spring, mate, and feed for several weeks, then lay orange-yellow eggs in the soil at the base of plants.
- Larvae usually hatch in 10 days, then feed on the roots of plants for 2–6 weeks. Fully-grown larvae are about 9 mm long. Pupation takes place in the soil, and adults emerge after about 1 week. There is only 1 generation per year in Ontario.
- The adult beetles damage plants by chewing on leaves, stems, and fruits, but the greatest damage comes from the wilt-causing bacteria they often carry in their gut.

The bacteria survive the winter in the gut of the overwintering beetles. In the spring, the beetles inoculate plants with the disease as they feed on the plant tissue.

- There is no control for the wilt once a plant is infected. Inoculated leaves generally wilt within 5–6 days, and the plant dies within 2 weeks. Striped cucumber beetles can also transmit cucumber mosaic virus.
- Best control comes from insect barriers installed over all greenhouse openings to exclude the adult beetles.

Symphylans

Symphylans are found under stones, in rotting wood, and in moist soil high in decaying organic matter. They are small white creatures resembling centipedes, with slender, long, white bodies (1–5 mm long), 10–12 pairs of legs, and long antennae. (Centipedes have 15 pairs of legs.)

- While centipedes are beneficial predators that prey on many insects, symphylans can feed on the roots of plants. On many crops, damage shows as tiny black marks on the roots where a hemispherical piece of tissue has been scooped out. Injured roots become stubby and the plant becomes stunted.
- Damage caused by symphylans to roots and root hairs provides entry points for root-rotting diseases.

Tomato Pinworm

The tomato pinworm (TPW) is a semi-tropical pest that can infest tomato crops in Ontario. It inflicts damage by feeding on tomato leaves and fruit.

- Other suitable hosts for TPW are potatoes and eggplant. Weeds such as nightshade and its relatives may also serve as hosts.
- The adult is a small, light-brown moth about 6 mm long. It is generally more active at night, laying most of its eggs on younger leaves during the first few nights of activity. Newly hatched larvae walk on the leaf surface for a very short time before entering the leaf to start mining. [***Plate 70***, ***Plate 71*** and ***Plate 72***]
- There are 4 larval stages, the first 2 of which are spent in the leaf. The 3rd and 4th stages may be found between 2 leaves knitted together, in a leaf that has been folded over, or inside fruits. Larvae characteristically enter fruits just beneath the calyx.
- Mature larvae may either remain on the plant or drop to the ground to pupate. On the ground, pupation usually occurs within the top 15 cm of soil. Tomato pinworms do not diapause. Their development continues year round, slowing during cold weather periods. Development time from egg to adult usually ranges between 19–70 days, depending on temperature. The life cycle is completed in 28 days at 24°C, and can be as short as 19 days at 30°C.

Control strategies include:

- Inspect all seedlings for larval feeding damage
- Destroy all old infested plants and any debris from infested crops
- Monitor for their presence with pheromone or light traps, and by inspecting crops regularly. Note that pheromone traps attract only male TPW, whereas light traps attract both sexes of TPW and many other insect species
- Hand-pick damaged leaves and destroy larvae within the mines
- Destroy weeds and stray tomato seedlings inside and around the greenhouse
- Install insect barriers over vents

For more information on this pest, see OMAFRA Factsheet, *Tomato Pinworm – Its Biology and Control Strategies for Greenhouse Tomato Crops* Order No. 98-009

Vertebrate Pests

Rats and mice may be very destructive in the greenhouse. They feed on almost any food source and can cause damage by gnawing and burrowing.

- Norway rats and field mice are the most common vertebrate inhabitants of greenhouses. Baits containing rodenticides such as chlorophacinone, diphacinone, warfarin, and zinc phosphide can give some control. The first 3 chemicals are anticoagulants, and multiple doses are usually required. Zinc phosphide is not an anticoagulant and is more acutely toxic—a single dose can achieve kill.
- Ensure that the toxic baits are placed in covered stations where pets cannot get them.
- To minimize the development of rodenticide resistance, particularly to the anticoagulants, always adopt other control measures:
  - store all potential food material in tight-fitting containers
  - use many traps where there are signs of activity, placing one trap every 2–3 metres along walls
  - set traps at right angles to the wall, with the bait and trigger facing the wall
  - handle traps with gloves to avoid contaminating them with human smells
  - try different baits. Suggested baits include peanut butter mixed with oats, raisins, gumdrops, or any other sticky food material, and cotton (which provides nesting material)
  - maintain several female cats as biological control agents. Female cats tend to be more predacious than males.

Root Nematodes

These are not a major problem in hydroponic vegetable production but are seen occasionally where poor greenhouse hygiene is practiced.

Plant parasitic nematodes are small (<1 mm long) worm-like organisms that live in the root media. They are broadly divided into 2 groups — ectoparasites (which attack plants externally) and endoparasites (which spend at least part of their life cycle within the plant tissue).

- All parasitic nematodes have stylets through which they inject saliva into the plant tissue. The saliva causes most of the damage. It results in necrosis or the proliferation of giant cells that produce galls.
- Nematodes cause damage mainly by reducing the ability of plants to absorb water and nutrients. Above ground symptoms of nematode damage include weakened plants that wilt in the sun, yellow or pale green leaves, and stunted fruit or flowers.
- Where nematocides are used between crops, nematode infestations often recur because of insufficient penetration of the chemicals into the lower soil levels. Soils so treated should always be properly aerated to avoid subsequent plant damage.

Root-Lesion Nematode, Pratylenchus penetrans (Cobb) —
This endoparasitic nematode is native to Ontario soils and can attack many floral and vegetable crops.

- All stages are thread-like and invisible to the naked eye.
- This nematode invades the outer layers of young roots, causing small brown-to-black elliptical lesions that merge to discolour the roots and kill them.

Northern Root-Knot Nematode, Meloidogyne hapla (Chitwood) —
This is another endoparasitic nematode native to Ontario soils. It attacks almost all types of vegetable crops and many floral crops, particularly roses, African violets, and geraniums.

- Early larval stages are thread-like and invisible, while later stages and adults are peanut-to-pearl shaped and just visible when dissected from roots.
- This nematode invades roots and settles down to cause swellings, knots, or galls, and excessive root proliferation. Infested roots do not necessarily become discoloured unless attacked by bacteria and fungi.

Dagger Nematode, Xiphinema diversicaudatum (Micoletzky) —
This ectoparasitic nematode is not native to Ontario and was introduced into greenhouses on plant stocks. Dagger nematodes prefer plants with woody roots, and are more frequently associated with crops such as strawberry, grapes, and roses.

- The nematode survives in the root crotches of the understock.
- One of the largest nematodes attacking plants, this 6 mm long, thread-like roundworm can, with care, be seen on the roots. It feeds on young roots from the soil, causing galls similar to root-knot galls but somewhat larger. These galls are actually curved swellings in the root tip area, accentuated with the necrosis and shriveling of roots above the galls.

Pin Nematode, Paratylenchus projectus (Jenkins) —
This nematode is native to Ontario and can attack many floral and vegetable greenhouse crops. All stages of pin nematode are thread-like and invisible to the naked eye.

- This species is active in both fine textured (clay) and coarse textured (sandy) soils.
- The pin nematode does not enter roots, but feeds at root tips by probing root hairs and surface cells. No specific root symptoms (such as galls or lesions) appear. Plants infested with this nematode show general above ground symptoms.

Southern Root-Knot Nematode, Meloidogyne incognita (Kofoid and White) —
This endoparasitic nematode is not native to Ontario, but has become persistent in the protected greenhouse environment. It cannot survive outdoors during winter. It is a bad problem on tomato and cucumber, but can also attack several floral and foliage crops.

- Root damage and symptoms differ from those of the northern root-knot nematode. Plants damaged by the southern root-knot nematode have larger galls and lack fine root growths from the galls.
- Tomato leaves may show phosphorus deficiency (purpling) on the underside, or downward curling of leaf edges; affected tomato or cucumber plants wilt readily.

Foliar Nematodes —
A few nematodes attack plant foliage. Symptoms caused by leaf-feeding nematodes are similar to those of several diseases and nutrient deficiencies.

13. Pesticides Registered for Greenhouse Vegetables

TABLE 13–1. Tomato Insect and Mite Pests

Pesticide	Rate	Pest	Pre-harvest Interval (days)	Remarks
Ambush 240 EC	420 mL/1000 L	whiteflies	1	
Avid	30 mL/100 L	two-spotted spider mite leafminer	3	No more than 5 applications/crop cycle
Dibrom	10 mL/100 m^3 Apply undiluted to cold pipes, then heat to 41°C and close greenhouse for at least 4 hr.	aphids, two-spotted spider mites, whiteflies	1	May cause injury to flowers. Ventilate greenhouse properly before re-entering.
Dipel WP	250–500 g/400 L	cabbage loopers	0	
Foray 48B	80–200 mL/1000 m^2	cabbage loopers	0	
Impower	16g/80 L water/1000 plants.	aphids, whiteflies	3	Do not apply more than once per season. There may be some repellency of bumble bees and negative effects on beneficials.
Insecticidal Soap	1–2 L/100 L	aphids, two-spotted spider mites, whiteflies, earwigs, psyllids		May cause damage to flowers under high temperature conditions
Nicotine Smoke	1 can/300 m^3	aphids, thrips	3	Ventilate greenhouse properly before re-entering
Parathion Smoke	1 can/300 m^3	aphids, caterpillars, spider mites, thrips, whiteflies, leaf rollers, leafhoppers, tarnished plant bug	1	Ventilate greenhouse properly before re-entering
Thiodan 4 EC Thicdan 50 WP	1.25–1.5 L/1000 L 1–1.5 kg/ha	aphids, whiteflies	2	
Vectobac	2–8 L /1000 L	fungus gnats	0	Do not mix and apply with fertilizers or fungicides containing copper or chlorine as this may neutralize the active ingredients.
Vendex 50W	50 g/100 L	two-spotted spider mites	5	

TABLE 13–2. Tomato Diseases

Pesticide	Rate	Disease	Pre-harvest Interval (days)	Remarks
Benlate 50WP + Manzate WP	1.1 kg Benlate + 2.25 kg Manzate	botrytis grey mould, leaf mould	7	Do not make more than 2 applications per crop.
Botran 75WP	1.75 kg/1000 L	botrytis grey mould	1	Seedlings may be injured by drenching.
Exotherm Termil	1 can/100 m^3	botrytis grey mould		Do not apply when greenhouse temperature is above 24°C. Be certain that all foliage and blossoms are dry. Ventilate greenhouse at least 2 hr before re-entering.
Maestro 80DF	1.25 kg/1000 L — apply 50–85 L/100 m^2	damping-off in seedlings		
Manzate DF	2.4 kg/ha	early and late blight, septoria leaf spot	7	
Mycostop	Immediately after transplanting: 10–50 mg/plant or 20–100mL/plant of 0.05% suspension	fusarium; root diseases; stem rot	0	Treatments to be repeated at intervals of 3–6 weeks depending on disease pressure
No-Damp	10 mL/1 L	damping-off diseases in seedlings		
Nova	340 g/ha (1000L water/ha)	powdery mildew	3	Apply no more than 2 applications per year
Rovral 50WP	1 kg/1000 L	botrytis grey mould	2	
Sulphur (Bartlett's Microscopic Sulphur 92 %)	750 g/1000 L/ha	powdery mildew	1	Maximum of 10 applications/crop cycle. May cause slight foliage damage.

TABLE 13–3. Cucumber Insect and Mite Pests

Pesticide	Rate	Pest	Pre-harvest Interval (days)	Remarks
Ambush 240 EC or Pounce EC	420 mL/1000 L 260 mL/1000 L	whiteflies	1	
Avid	30 mL/100 L	two-spotted spider mite leafminer	3	No more than 5 applications/crop cycle
Impower		whiteflies, aphids		
Dibrom	10 mL/100 m^3 Apply undiluted to cold pipes, then heat to 41°C and close greenhouse for at least 4 hr	aphids, spider mites, whiteflies, mealy bugs, leafrollers	1	May cause injury to flowers. Ventilate greenhouse properly before re-entering
Dyno–Mite	284 g/ha 1000L water/ha	two-spotted spider mites	2	Maximum number of applications per crop cycle is 2. Apply at intervals of at least 28 days.
Foray 48B	80–200 mL/1000 m^2	cabbage loopers	0	
Impower	16 g/80 L water/ 1000 mature plants	aphids, whiteflies	3	Do not apply more than once per season. There may be negative effects on some beneficials.
Insecticidal Soap	1–2 L/100 L	aphids, two-spotted spider mites, whiteflies, earwigs, psyllids		May cause damage to plant under high temperature conditions
Nicotine Smoke	1 can/300 m^3	aphids, thrips	3	Ventilate greenhouse properly before re-entering
Parathion Smoke	1 can/300 m^3	aphids, caterpillars, spider mites, thrips, whiteflies, leafhoppers, leafrollers, tarnished plant bug	1	Can damage cucumber seedlings. Ventilate greenhouse properly before re-entering
Thiodan 4 EC Thiodan 50 WP	1.25–1.5 L/1000L 1–1.5 kg/ha	aphids, whiteflies	2	
Vectobac	2–8 L/1000 L	fungus gnats	0	Do not mix and apply with fertilizers or fungicides containing copper or chlorine as this may neutralize the active ingredients.
Vendex 50W	50 g/100 L	two-spotted spider mites	3	

TABLE 13–4. Cucumber Diseases

Pesticide	Rate	Disease	Pre-harvest Interval (days)	Remarks
Benlate 50WP + Manzate DF	550–850g Benlate + 2.25 kg Manzate	gummy stem blight, powdery mildew	7	Do not make more than 2 applications per crop.
Mycostop	Immediately after transplanting: 10–50 mg/plant or 20–100mL/ plant of 0.05% suspension	fusarium; root diseases; stem rot	0	Treatments to be repeated at intervals of 3–6 weeks depending on disease pressure
No-Damp	10 mL/1 L	damping-off diseases in seedlings		
Nova	340 g/ha	powdery mildew, gummy stem blight	2	Do not apply more than 6 times per year
Previcur	10 mL/10 L of water and apply this solution at rate of 100–200 mL/ plant. Use higher rate for 2nd and 3rd applications.	pythium root rot	14	Maximum of 3 applications per season. Occasional slight damage may occur following overhead drenching of recently planted seedlings.
Rovral	1 kg/1000 L	botrytis grey mould, gummy stem blight	2	
Microfine Sulphur 92 (Zeneca)	150 g per 100 L	powdery mildew	1	Can cause damage if applied under hot, humid conditions.

TABLE 13–5. Pepper Insect and Mite Pests

Pesticide	Rate	Pest	Pre-harvest Interval (days)	Remarks
Avid	30 mL/100 L	two-spotted spider mite	3	
Basudin 500 EC or Diazinon 500	230 mL/250 L/4000 m^2 0.575 L/625 L water	aphids	5	
Confirm	0.5 L/ha; apply in 4000 L water/ha	European corn borer	3	Ensure good coverage and apply at intervals of approximately 7 days. Do not exceed 4 applications per year. Re-entry interval is 12 hr.
Dipel WP	150–300 g/250 L/4000 m^2	cabbage loopers	0	
Dyno–Mite	284 g/ha	two-spotted spider mite	3	Maximum number of applications per year is 2.
Foray 48B	80–200 mL/1000 m^2	cabbage loopers	0	
Insecticidal Soap	1–2 L/100 L	aphids, spider mites, whiteflies, earwigs, psyllids	5	May cause damage to plant under high temperature conditions
Nicotine Smoke	1 can/300 m^3	aphids, thrips	5	Ventilate greenhouse properly before re-entering
Thiodan 4 EC	1.25–1.5 L/1000 L	lygus bug or tarnished plant bug, aphids	2	Do not apply more than twice per season
Vectobac	2–8 L/1000 L	fungus gnats	0	Do not mix and apply with fertilizers or fungicides containing copper or chlorine as this may neutralize the active ingredients.

TABLE 13–6. Pepper Diseases

Pesticide	Rate	Disease	Pre-harvest Interval (days)	Remarks
Maestro 80DF	1.25 kg/1000 L – apply 50–85 L/100 m^2	damping-off in seedlings		
Mycostop	Immediately after transplanting: 10–50 mg/plant or 20–100ml/plant of 0.05% suspension	fusarium; root diseases; stem rot	0	Treatments to be repeated at intervals of 3–6 weeks depending on disease pressure
No-Damp	10 mL/1 L	damping-off diseases in seedlings		
Nova	340 g/ha using 1500–3000 L water/ha.	powdery mildew	3	Apply as soon as possible after initial infection and again 12 days later when disease pressure warrants control. Maximum number of applications per crop cycle is 3. Re-entry interval is 12 hr.

TABLE 13–7. Lettuce Insect and Mite Pests

Pesticide	Rate	Pest	Pre-harvest Interval (days)	Remarks
Foray 48B	80–200 mL/1000 m^2	cabbage loopers	0	
Insecticidal Soap	1–2 L/100 L	aphids, spider mites, whiteflies, earwigs, psyllids		May cause damage to plant under high temperature conditions
Malathion 25W	2.75–5.5 kg/ha	aphids, caterpillars, spider mites, thrips, whiteflies	Leaf = 21 Head = 7	Do not apply more than twice per season
Nicotine Smoke	1 can/300 m^3	aphids, thrips	7	Ventilate greenhouse properly before re-entering
Plantfume Parathion	1 can/300m^3	green peach aphids	7	Do not apply more than twice per season. Ventilate greenhouse properly before re-entering
Thiodan 4 EC	1.25–1.5 L/1000 L	aphids	14	Only one application per crop; low volume mist or high volume spray.
Vectobac	2–8 L/1000 L	fungus gnats	0	Do not mix and apply with fertilizers or fungicides containing copper or chlorine as this may neutralize the active ingredients.

TABLE 13–8. Lettuce Diseases

Pesticide	Rate	Pest	Pre-harvest Interval (days)	Remarks
No-Damp	10 mL/1 L	damping-off diseases in seedlings		
Rovral	1 kg/1000 L	botrytis grey mould	14	

Appendices

APPENDIX A. Ontario Ministry of Agriculture, Food and Rural Affairs Advisory Staff

Service	Staff	Address	Contact	email
	Gillian Ferguson Greenhouse Vegetable IPM Specialist	Greenhouse and Processing Crops Research Centre 2585 County Road 20, Harrow, ON N0R 1G0	**Tel**: (519) 738-2251 Ext. 406 **Fax**:(519) 738-4564	gillian.ferguson @omafra.gov.on.ca
	Shalin Khosla Greenhouse Vegetable Specialist	Greenhouse and Processing Crops Research Centre 2585 County Road 20, Harrow, ON N0R 1G0	**Tel**: (519) 738-2251 Ext. 405 **Fax**:(519) 738-4564	shalin.khosla @omafra.gov.on.ca

Greenhouse Information: www.gov.on.ca/OMAFRA/english/crops/hort/greenhouse.html

APPENDIX B. Ontario Ministry of the Environment Pesticides Control Offices

Region/County	Pesticides Officer Address	Telephone/Fax
Central Region Toronto, Halton, Peel, York, Durham	Charles Zubovits 5775 Yonge Street, 8th Floor Toronto, Ontario M2M 4J1	Tel (416) 326-3671 Toll Free 1-800-810-8048 Fax (416) 325-6347
West-Central Region Haldimand-Norfolk, Niagara, Hamilton-Wentworth, Dufferin, Wellington, Waterloo, Brant	Paul McCubbin Linda Dennie Ontario Government Building 119 King Street West, 12th Floor Hamilton, Ontario L8N 3Z9	Tel (905) 521-7667 (905) 521-7658 Fax (905) 521-7820
Eastern Region Frontenac, Hastings, Lennox & Addington, Prince Edward, Leeds & Grenville, Prescott & Russell, Stormont/Dundas & Glengarry, Peterborough, Victoria, Northumberland, Renfrew, Ottawa-Carleton, Lanark, District of Nipissing (Townships of Airy, Murchison, Dickens, Lyell and Sabine)	Andrew Morley 133 Dalton Avenue Kingston, Ontario K7L 4X6	Tel (613) 549-4000, x 2684 Fax (613) 548-6908 Toll Free 1-800-267-0974
Southwestern Region Elgin, Middlesex, Oxford, Essex, Kent, Lambton, Bruce, Grey, Huron, Perth,Simcoe	Doug Morrow Wray Lampman 659 Exeter Road, 2nd Floor London, Ontario N6E 1L3	Tel (519) 873-5047 (519) 873-5048 Fax (519) 873-5000
Northern Region Manitoulin, Nipissing, Parry Sound, Sudbury, Algoma East, Cochrane East, Haliburton, Muskoka, Kenora, Rainy River, Thunder Bay, Algoma West, Cochrane West	Ray Potvin John Negusanti 199 Larch Street, Suite 1101 Sudbury, Ontario P3E 5P9	Tel (705) 564-3247 (705) 564-3249 Fax (705) 564-4180
Standards Development Branch	Pesticides Section (Mailing Address) 135 St. Clair Avenue West Toronto, Ontario M4V 1P5	Tel (416) 327-5519 Fax (416) 327-2936
Approvals Branch	Pesticides Licensing 250 Davisville Avenue, 3rd Floor Toronto, Ontario M4S 1H2	Tel (416) 440-3584 Toll Free 1-800-461-6290 Fax (416) 440-6973

APPENDIX C. Accredited Soil Testing Laboratories in Ontario

The following labs are accredited to perform soil tests for pH, buffer pH, P, K, Mg and Nitrate-N on Ontario soils.

A & L Canada Laboratories East, Inc.
2136 Jetstream Road
London, Ontario N5V 3P5
Tel (519) 457-2575
Fax (519) 457-2664
web sitewww.al-labs-can.com
email aginfo@al-labs-can.com
Contact Mr. Greg Patterson
Mr. Ian McLachlin

Accutest Laboratories
146 Colonnade Road, Unit #8
Nepean, Ontario K2E 7Y1
Tel (613) 727-5692
Fax (613) 727-5222
web sitewww.accutestlabs.com
email phaulena@accutestlabs.com
Contact Mrs. Lorna Wilson
Mr. Peter Haulena

Agri-Food Laboratories
503 Imperial Road, Unit #1
Guelph, Ontario N1H 6T9
Tel (519) 837-1600, 1-800-265-7175
Fax (519) 837-1242
web site:www.agtest.com
email lab@agtest.com
ContactMr. Dale Cowan
Ms. Nora Wilson

Soil and Nutrient Laboratory
(formerly Analytical Services, Land Resource Science)
University of Guelph
P.O. Box 3650, 95 Stone Road West
Guelph, Ontario N1H 2W1
Tel (519) 767-6226
Fax (519) 767-6240
email vkerslak@lsd.uoguelph.ca
ContactMs. Viriginia Kerslake

Stratford Agri Analysis Inc.
(A Daco Laboratories Ltd. company)
1131 Erie Street, Box 760
Stratford, Ontario N5A 6W1
Tel (519) 273-4411, 1-800-323-9089
Fax (519) 273-4411
email saa@dacolabs.com
ContactMr. Dale Peters
Mr. Gary Roberts
Mr. Keith Lemp

Agriculture & Agri-Food Canada Research Centres

Eastern Cereals and Oilseeds Research Centre
960 Carling Avenue
Ottawa, K1A 0C6
Tel (613) 759-1952
http://res2agr.ca/ecorc/welcome.htm

Greenhouse and Processing Crops Centre
Harrow N0R 1G0
Tel (519) 738-2251
http://res2.agr.ca/harrow/

Southern Crop Protection and Food Research Centre
http://res2.agr.ca/london/pmrc/pmrchome.html

1391 Sandford Street
London N5V 4T3
Tel (519) 457-1470

Vineland Research Farm
4902 Victoria Avenue North
Vineland L0R 2E0
Tel (905) 562-4113

Delhi Research Farm
Box 186 Schafer Road
Delhi N4B 2W9
Tel (519) 582-1950

Canadian Food Inspection Agency Regional Offices (Plant Protection)

www.cifa-acia.agr.ca

Belleville
345 College Street East
Belleville, K8N 5S7
Tel (613) 969-3333

Brantford
Federal Building, Dalhousie & Queen St., P.O. Box 637
Brantford, N3T 5P9
Tel (519) 751-8157

Hamilton
709 Main Street West, Suite 101
Hamilton, L8S 1A2
Tel (905) 572-4152

London
457 Richmond Street, Suite 404
London, N6A 3E3
Tel (519) 645-4021

Niagara Falls
Mailing address: P.O. Box 35, Niagara Falls, L2E 6S8
Street address: 4551 Zimmerman Avenue
Niagara Falls, L2E 3M5
Tel (905) 357-5981

Ottawa District
3 Observatory Crescent
Building #3 Central, Experimental Farm
Ottawa, K1A 0C9
Tel (613) 759-1571

Toronto
401 Champagne Drive, Unit 1
Downsview, M3J 2C6
Tel (416) 954-1714

Windsor
441 University Avenue West, Suite 208
Windsor, N9A 5P9
Tel (519) 252-7095

University of Guelph

Main Campus
Guelph, N1G 2W1
Tel (519) 824-4120
www.uoguelph.ca

Alfred College
Alfred, K0B 1A0
Tel (613) 679-2218
www.alfredc.uoguelph.ca

Kemptville College
Kemptville, K0G 1J0
Tel (613) 258-8336
www.kepmtvillec.uoguelph.ca

Ridgetown College
Ridgetown, N0P 2C0
Tel (519) 674-1500
www.ridgetownc.on.ca

Department of Plant Agriculture
www.plant.uoguelph.ca

Department of Plant Agriculture, Kettleby
1125 Woodchopper's Lane, R.R. #1
Kettleby, L0G 1J0
Tel (905) 775-3783

Department of Plant Agriculture, Simcoe
Box 587 Blue Line Road
Simcoe, N3Y 4N5
Tel (519) 426-7127

Department of Plant Agriculture, Vineland
Box 7000, 4890 Victoria Avenue North
Vineland Station, L0R 2E0
Tel (905) 562-4141

Lab Services Division
www.uoguelph.ca/labserv/

Pesticide and Trace Contaminants
P.O. Box 3650, 95 Stone Road West
Guelph, N1H 8J7
Tel (519) 767-6200

Pest Diagnostic Clinic
Tel (519) 767-6256

APPENDIX E. Diagnostic Service

Samples for disease diagnosis, insect or weed identification, nematode counts and Verticillium testing can be sent to:

Pest Diagnostic Clinic
Laboratory Services Division
University of Guelph
95 Stone Road West
Guelph Ontario, N1H 8J7
Tel (519) 767-6256
Fax (519) 767-6240
E-mail pdc@lsd.uoguelph.ca

Payment must accompany samples at the time of submission.

Please make cheque payable to the University of Guelph. Additional charges will be invoiced with the final report. VISA and Mastercard are also accepted. Please do not mail cash

How to Sample for Nematodes

Soil

When to Sample

Soil and root samples can be taken at any time of the year that the soil is not frozen. In Ontario, nematode soil population levels are generally at their highest in May and June and again in September and October.

How to Sample Soil

Use a soil sampling tube, trowel or narrow-bladed shovel to take samples. Sample soil to a depth of 20–25 cm (8–10 in.). If the soil is bare, remove the top 2 cm (1 in.) prior to sampling. A sample should consist of 10 or more subsamples combined. Mix well. Then take a sample of 1/2–1 L (1 pint–1 quart) from this. No one sample should represent more than 2.5 ha (6.25 ac). Mix subsamples in a clean pail or plastic bag.

Sampling Pattern

If living crop plants are present in the sample area, take samples within the row and from the area of the feeder root zone (with trees, this is the drip line).

Number of Subsamples

Based on the total area sampled:
500 m^2 (5,400 ft^2)10 subsamples
500 m^2–0.5 ha (5,400 ft^2–1.25 ac)25 subsamples
0.5 ha–2.5 ha (1.25–6.25 ac)50 subsamples

Roots

From small plants, sample the entire root system plus adhering soil. For large plants, 10–20 g (1/2–1 oz.) dig fresh weight from the feeder root zone and submit.

Submitting Plant for Disease Diagnosis or Identification

Problem Areas

Take soil and root samples from the margins of the problem area where the plants are still living. If possible, also take samples from healthy areas in the same field. If possible, take both soil and root samples from problem and healthy areas in the same field.

Sample Handling

Soil Samples

Place in plastic bags as soon as possible after collecting.

Root Samples

Place in plastic bags and cover with moist soil from the sample area.

Storage

Store samples at 5–10°C (40–50°F) and do not expose them to direct sunlight or extreme heat or cold (freezing). **Only living nematodes can be counted. Accurate counts depend on proper handling of samples.**

Fee Schedule

Procedures	**Price/ Sample**
Plant Diseases	
Diagnosis not requiring plating	$25.00
Diagnosis requiring plating	$40.00
Turf diagnosis	$50.00
Bacterial identification using Biolog®	$95.00
Detection of virus using Transmission Electron Microscopy	$85.00
Detection of virus using ELISA (turnaround time = 5 working days)	$60.00
Detection of virus using ELISA (RUSH: 24-hour turnaround. Available for samples received Monday through Thursday. Each additional sample is $20.00. ELISA tests not available for all viruses, contact clinic staff for details.)	$120 for 1–6 samples
Weed identification	$40.00
Insects	
Basic identification	$25.00
Identification requiring dissection and/or extensive keys	$40.00
Nematode and Verticillium Counts	**Price/Sample**
Nematodes extracted from soil (Bearman Pan Method)	$25.00
Nematodes extracted from roots	$60.00
Verticillium count	$60.00
SCN cyst count + egg count	$35.00

A minimum fee of $25.00 should accompany all submissions.

Sample Submission Forms

Carefully fill in all of the categories on the form. In the space provided, draw the most obvious symptom and the pattern of the disease in the field. It is important to include the cropping history of the area for the past 3 years and this year's pesticide use records.

Choose a complete, representative sample showing early symptoms. Submit as much of the plant as is practical, including the root system, or several plants showing a range of symptoms. For turfgrass, submit a 10–15 cm^2 piece of turf, including thatch and at least 5 cm of soil. Take the sample from the outside edge of a ring or patch, and include healthy and unhealthy turf, as well as the interface between. If symptoms are general, collect the sample from an area where they are of intermediate severity. **Completely dead material is usually inadequate for diagnosis**.

With plant specimens submitted for identification, include at least a 20–25-cm sample of the top portion of the stem with lateral buds, leaves, flowers or fruits in identifiable condition. Wrap plants in newspaper and put in a plastic bag. Tie the root system off in a separate plastic bag to avoid drying out and contamination of the leaves by soil. Do **NOT** add moisture, as this encourages decay in transit. Cushion specimens and pack in a sturdy box to avoid damage during shipping. Avoid leaving specimens to bake or freeze in a vehicle or in a location where they could deteriorate.

Delivery

Deliver to the Pest Diagnostic Clinic as soon as possible by first class mail or by courier at the beginning of the week.

Submitting Insect Specimens for Identification

Collecting Samples

Place dead, hard-bodied insects and spiders in vials or boxes and cushion with tissues or cotton. Place soft-bodied insects and caterpillars in vials containing alcohol. Do not use water, as this results in rot. Do not tape insects to paper or send them loose in an envelope.

Place live insects in a container with enough plant "food" to support them during transit. Be sure to write "live" on the outside of the container.

APPENDIX F. The Metric System

Metric Units

Linear Measures (length)

10 millimetres (mm) = 1 centimetre (cm)

100 centimetres (cm) = 1 metre (m)

1,000 metres = 1 kilometre (km)

Square Measures (area)

100 m X 100 m = 10,000 m^2 = 1 hectare (ha)

100 ha = 1 square kilometre (km^2)

Cubic Measures (volume)

Dry Measure

1,000 cubic millimetres (mm^3) = 1 cubic centimetre (cm^3)

1,000,000 cm^3 = 1 cubic metre (m^3)

Liquid Measure

1,000 millilitres (mL) = 1 litre (L)

100 L = 1 hectolitre (hL)

Weight-Volume Equivalents (for water)

(1.00 kg) 1,000 grams = 1 litre (1.00 L)

(0.50 kg) 500 g = 500 mL (0.50 L)

(0.10 kg) 100 g = 100 mL (0.10 L)

(0.01 kg) 10 g = 10 mL (0.01 L)

(0.001 kg) 1 g = 1 mL (0.001 L)

Weight Measures

1,000 milligrams (mg) = 1 gram (g)

1,000 g = 1 kilogram (kg)

1,000 kg = 1 tonne (t)

1 mg/kg = 1 part per million (ppm)

Dry–Liquid Equivalents

1 cm^3 = 1 mL

1 m^3 = 1000 L

Application Rate Conversations

Metric to Imperial (Approximate)

litres per hectare x 0.09 = gallons per acre

litres per hectare x 0.36 = quarts per acre

litres per hectare x 0.71 = pints per acre

millilitres per hectare x 0.015 = fluid ounces per acre

grams per hectare x 0.015 = ounces per acre

kilograms per hectare x 0.89 = pounds per acre

tonnes per hectare x 0.45 = tons per acre

Imperial to Metric (Approximate)

gallons per acre x 11.23 = litres per hectare (L/ha)

quarts per acre x 2.8 = litres per hectare (L/ha)

pints per acre x 1.4 = litres per hectare (L/ha)

fluid ounces per acre x 70 = millilitres per hectare (mL/ha)

tons per acre x 2.24 = tonnes per hectare (t/ha)

pounds per acre x 1.12 = kilograms per hectare (kg/ha)

ounces per acre x 70 = grams per hectare (g/ha)

Liquid Equivalents

Litres/Hectare		*Approximate Gallons/Acre*
50	=	5
100	=	10
150	=	15
200	=	20
250	=	25
300	=	30

Dry Weight Equivalents

Grams or Kilograms / Hectare		*Ounces or Pounds /Acre*
100 grams	=	1 1/2 ounces
200 grams	=	3 ounces
300 grams	=	4 1/4 ounces
500 grams	=	7 ounces
700 grams	=	10 ounces
1.10 kilograms	=	1 pound
1.50 kilograms	=	1 1/4 pounds
2.00 kilograms	=	1 3/4 pounds
2.50 kilograms	=	2 1/4 pounds
3.25 kilograms	=	3 pounds
4.00 kilograms	=	3 1/2 pounds
5.00 kilograms	=	4 1/2 pounds
6.00 kilograms	=	5 1/4 pounds
7.50 kilograms	=	6 3/4 pounds
9.00 kilograms	=	8 pounds
11.00 kilograms	=	10 pounds
13.00 kilograms	=	11 1/2 pounds
15.0 kilograms	=	13 1/2 pounds

Metric Conversions

5 mL = 1 tsp

15 mL = 1 tbsp

28.5 mL = 1 fl. oz

Conversion Tables — Metric to Imperial

Length

1 millimetre (mm) = 0.04 inch
1 centimetre (cm) = 0.40 inch
1 metre (m) = 39.40 inches
1 metre (m) = 3.28 feet
1 metre (m) = 1.09 yards
1 kilometre (km) = 0.62 mile

Area

1 square centimetre (cm^2) = 0.16 square inch
1 square metre (m^2) = 10.77 square feet
1 square metre (m$^{2)}$ = 1.20 square yards
1 square kilometre (km^2) = 0.39 square mile
1 hectare (ha) = 107,636 square feet
1 hectare (ha) = 2.5 acres

Volume (dry)

1 cubic centimetre (cm^3) = 0.061 cubic inch
1 cubic metre (m^3) = 1.31 cubic yards
1 cubic metre (m^3) = 35.31 cubic feet
1,000 cubic metres (m^3) = 0.81 acre-foot
1 hectolitre (hL) = 2.8 bushels

Volume (liquid)

1 millilitre (mL) = 0.035 fluid ounce
1 litre (L) = 1.76 pints
1 litre (L) = 0.88 quart
1 litre (L) = 0.22 gallon (Imp.)
1 litre (L) = 0.26 gallon (U.S.)

Weight

1 gram (g) = 0.035 ounce
1 kilogram (kg) = 2.21 pounds
1 tonne (t) = 1.10 short tons
1 tonne (t) = 2,205 pounds

Pressure

1 kilopascal (kPa) = 0.15 pounds/in^2

Speed

1 metre per second = 3.28 feet per second
1 metre per second = 2.24 miles per hour
1 kilometre per hour = 0.62 mile per hour

Temperature

°F = (°C X 9/5) + 32

Conversion Tables — Imperial to Metric

Length

1 inch = 2.54 cm
1 foot = 0.30 m
1 yard = 0.91 m
1 mile = 1.61 km

Area

1 square foot = 0.09 m^2
1 square yard = 0.84 m^2
1 acre = 0.40 ha

Volume (dry)

1 cubic yard = 0.76 m^3
1 bushel = 36.37 L

Volume (liquid)

1 fluid ounce (Imp.) = 28.41 mL
1 pint (Imp.) = 0.57 L
1 gallon (Imp.) = 4.55 L
1 gallon (U.S.) = 3.79 L

Weight

1 ounce = 28.35 g
1 pound = 453.6 g
1 ton = 0.91 tonne

Pressure

1 pound per square inch = 6.90 kPa

Temperature

°C = (°F – 32) x 5/9

Abbreviations

% = per cent (by weight)
ai = active ingredient
AP = agricultural powder
cm = centimetre
cm^2 = square centimetre
DG = dispersible granular
DP = dispersible powder
E = emulsifiable
e.g. = for example
EC = emulsifiable concentrate
F = flowable
g = gram
Gr = granules, granular
ha = hectare
kg = kilogram

km/h = kilometres per hour
kPa = kilopascal
L = litre
m = metre
m/s = metres per second
m^2 = square metre
mL = millilitre
mm = millimetre
SC = sprayable concentrate
SP = soluble powder
t = tonne
W = wettable (powder)
WDG = water dispersible granular
WP = wettable powder
km/h = kilometres per hour

Colour Plates

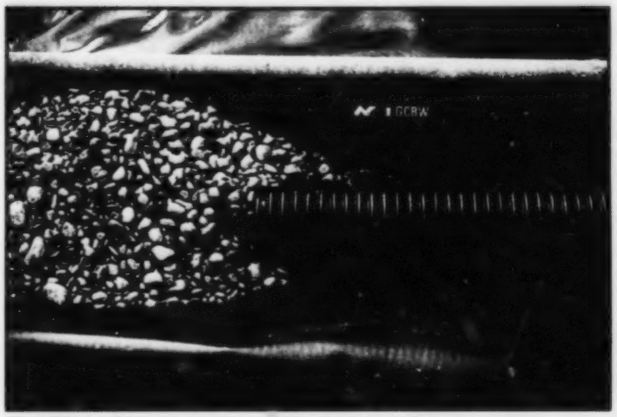


PLATE 1. Basic set up for closed rockwool production

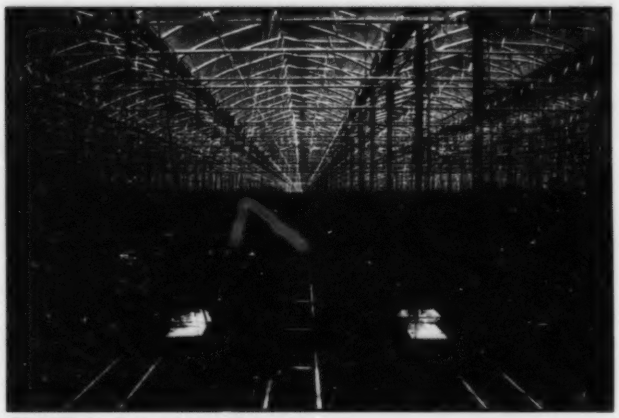


PLATE 2. Raised trough system

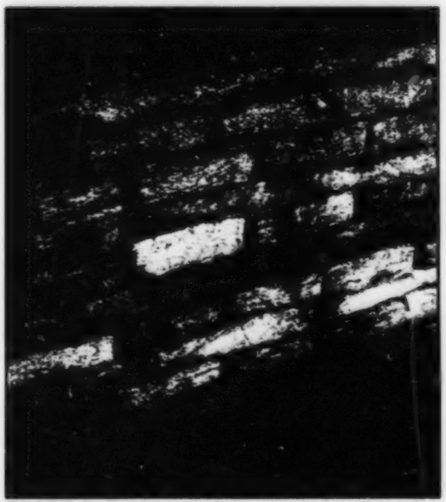


PLATE 3. Rockwool slabs ready for steaming

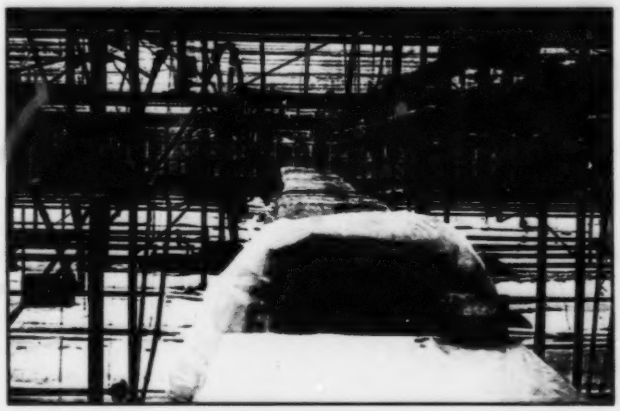


PLATE 4. Steaming of rockwool slabs

PLATE 5. Set up for seed germination

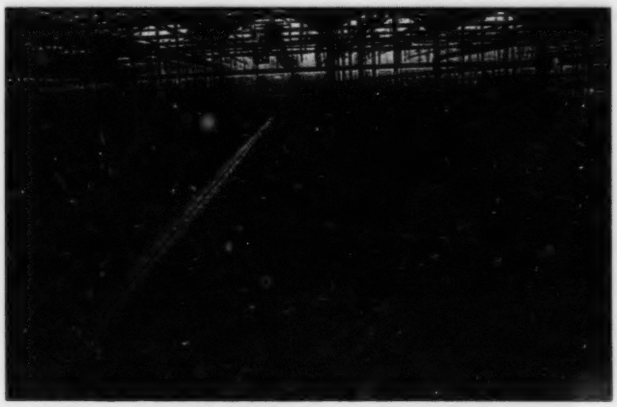


PLATE 6. Transplant raising

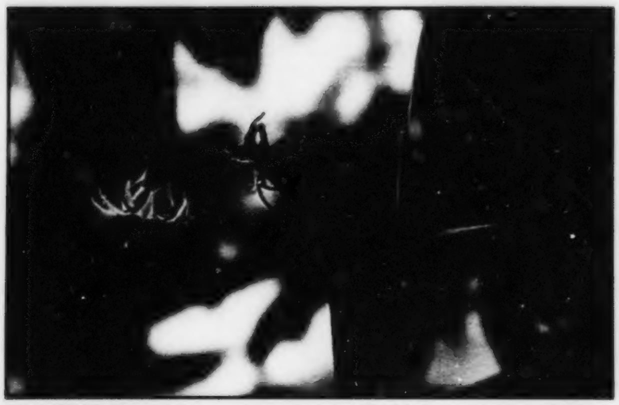


PLATE 7. Flower development — stalk slightly long, requiring support

PLATE 8. Split cluster: low night temperature at the early bud development stage

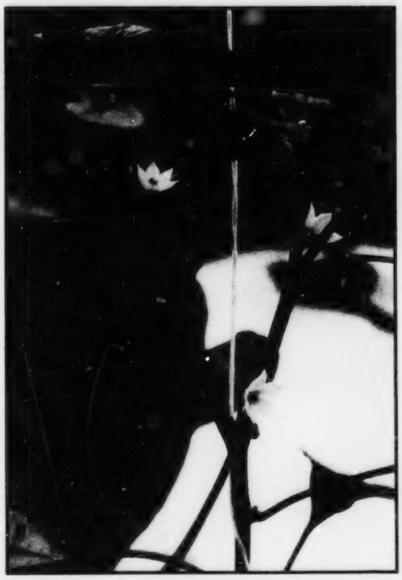
PLATE 9. Tomato truss too long, resulting in kinking of stalk

PLATE 10. Truss support to prevent kinking

PLATE 11. Bumble bee visiting tomato flower

PLATE 12. Tomato flower showing marks caused by bumble bee visit. Indication of good pollination

PLATE 13. Young pepper plant showing split stem and first flower (king flower) on the first level)



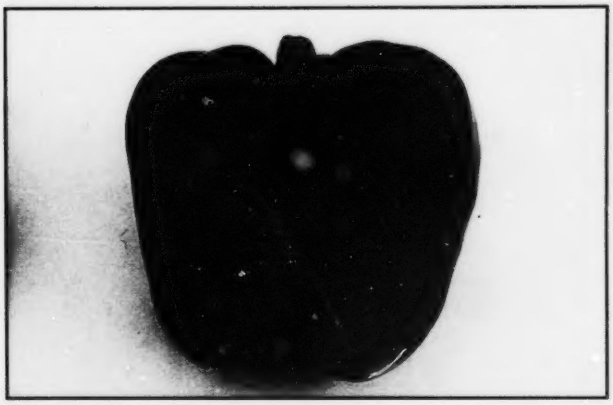


PLATE 14. Sunscald

PLATE 15. Sunburn on pepper surface due to poor canopy and direct light on fruit surface

PLATE 16. Elephant's foot

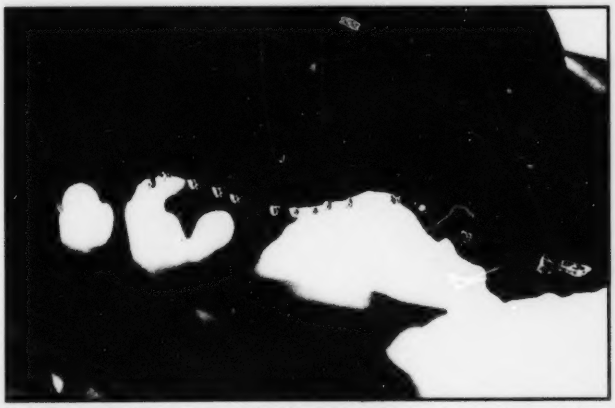


PLATE 17. High humidity in greenhouse causing water condensation. This increases incidence of gummy stem blight, botrytis and penicillium stem rot

PLATE 18. Damping-off

PLATE 19. Fusarium crown and root rot

PLATE 20. Grey mould

PLATE 21. Grey mould ghost spot

PLATE 22. Powdery mildew

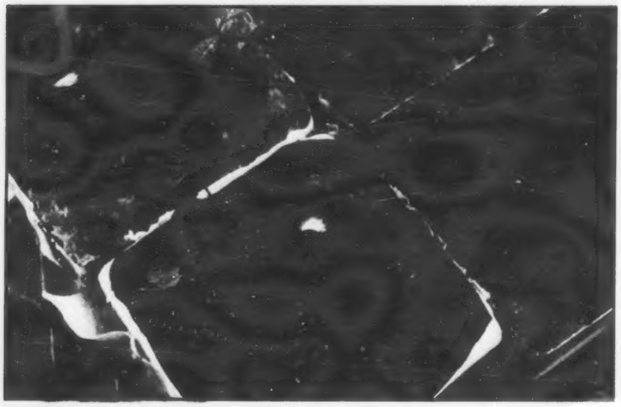


PLATE 23. Powdery mildew

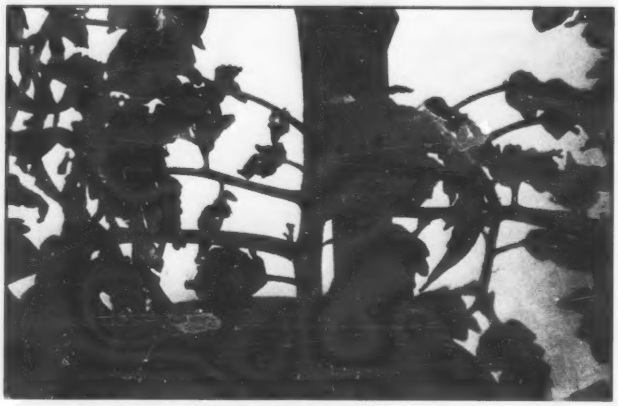


PLATE 24. Canker — one sided wilting

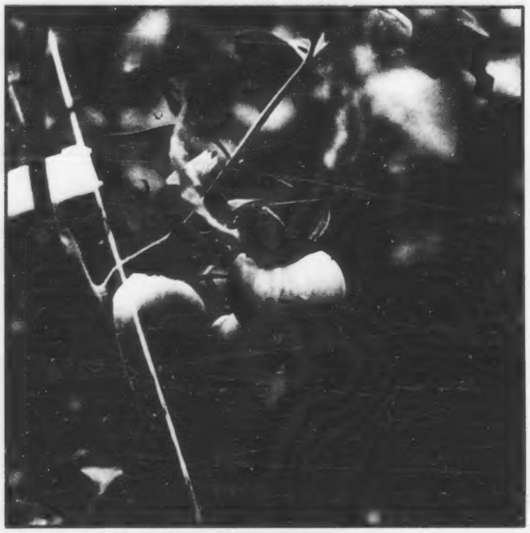


PLATE 25. Canker — fruit mottling

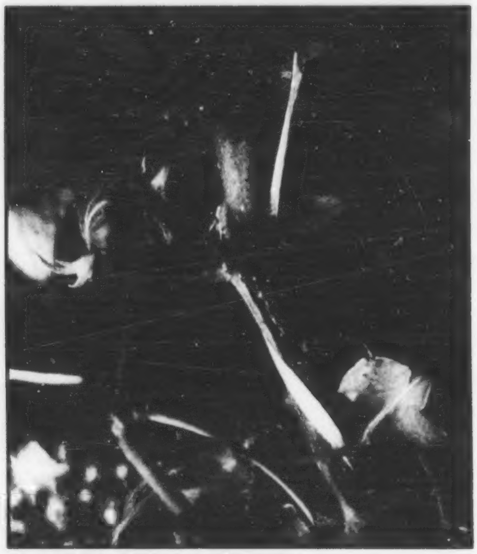


PLATE 26. Bacterial stem rot

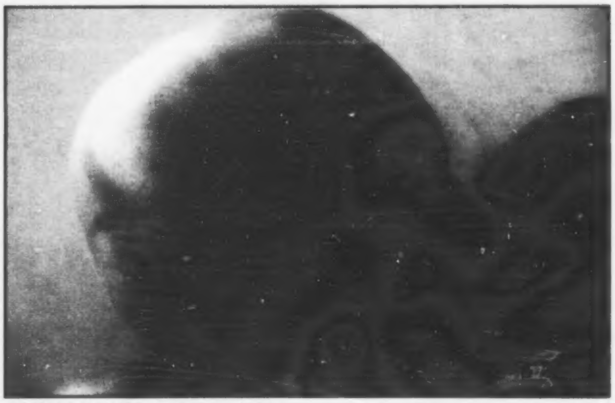


PLATE 27. Blossom end rot

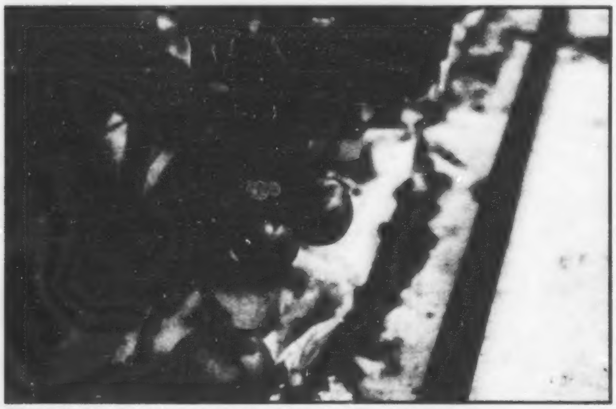


PLATE 28. Blotchy ripening due to low potassium

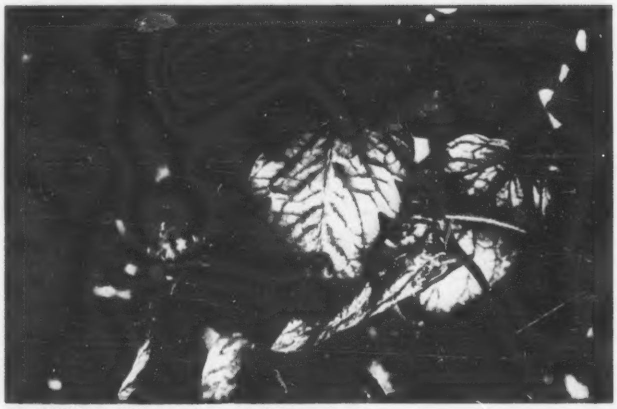


PLATE 29. Magnesium deficiency

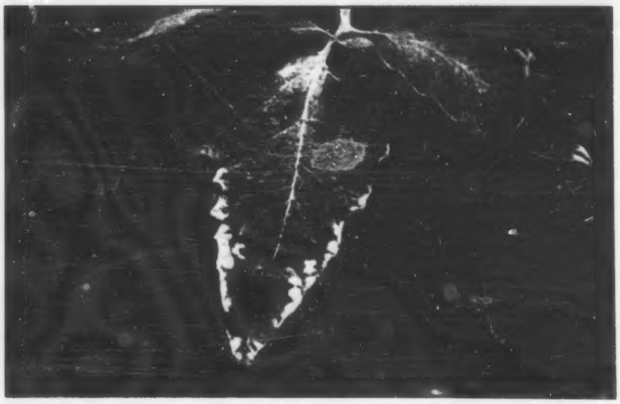


PLATE 30. Environmental stress resulting in poor Ca and K movement to leaf's edge

PLATE 31. Iron deficiency

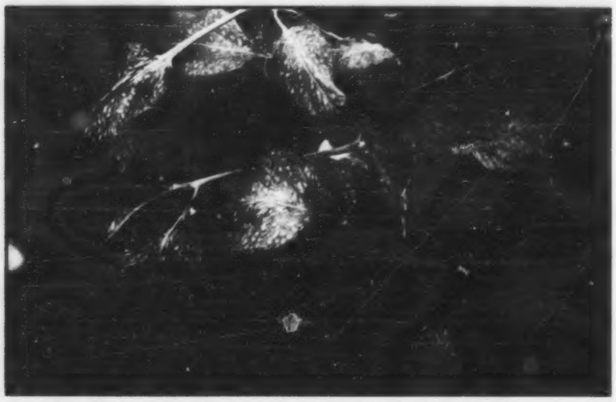


PLATE 32. Iron deficiency due to poor root environment as a result of over watering

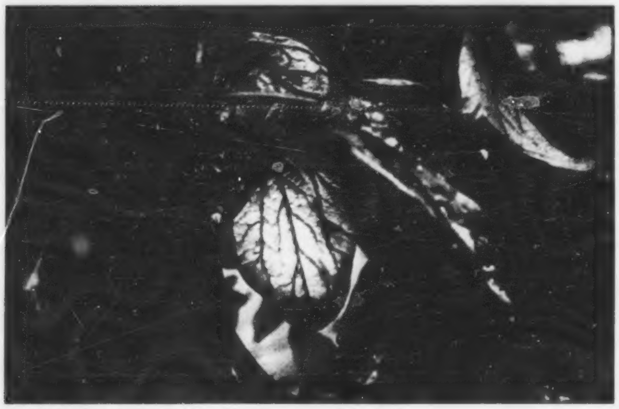


PLATE 33. Boron deficiency

PLATE 34. Russetting

PLATE 35. Green shoulder

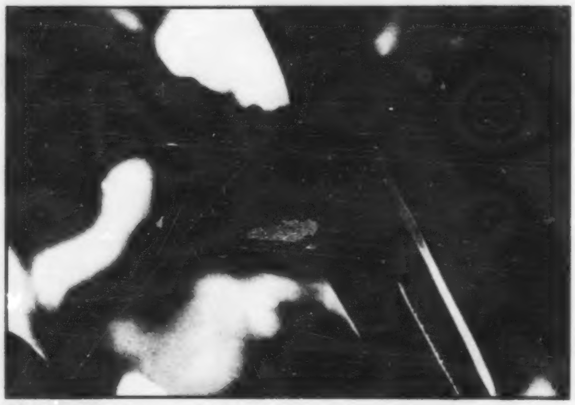


PLATE 36. Grey mould

PLATE 37. Gummy stem blight on stem

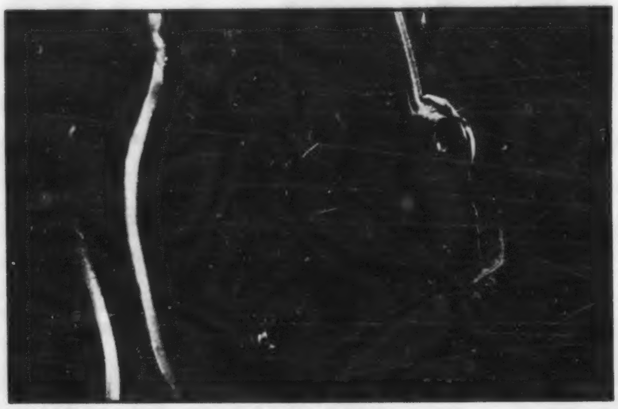


PLATE 38. Gummy stem blight on fruit

PLATE 39. Penicillum stem rot

PLATE 40. Leaf spot

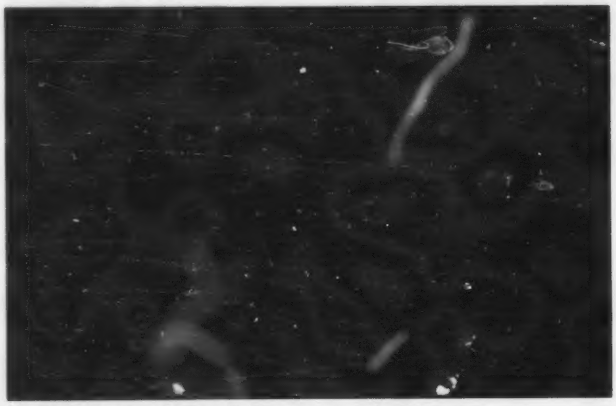


PLATE 41. Powdery mildew on cucumbers

PLATE 42. Fusarium wilt of cucumbers

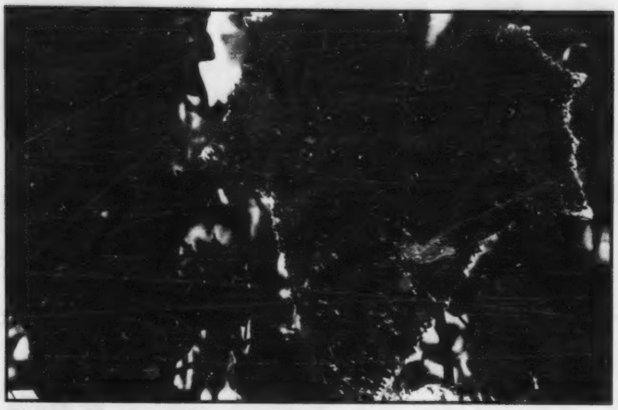


PLATE 43. Cucumber mosaic on leaf

PLATE 44. Cucumber mosaic on fruit

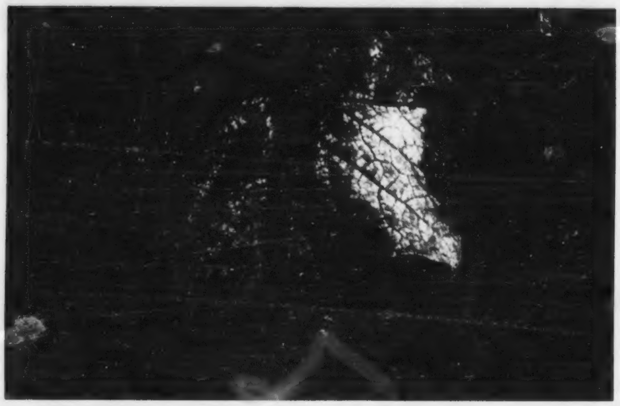


PLATE 45. Pseudo yellow virus

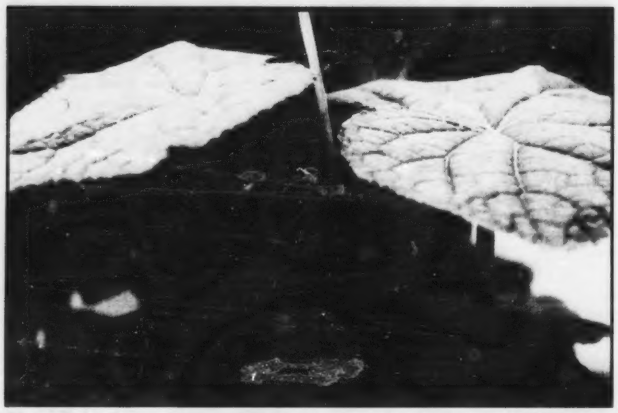


PLATE 46. Loss of growing point caused by calcium deficiency due to low calcium supply and rapid growth on young cucmber shoots

PLATE 47. Young cucumber leaf showing iron deficiency symptoms due to rapid growth and heavy fruit load

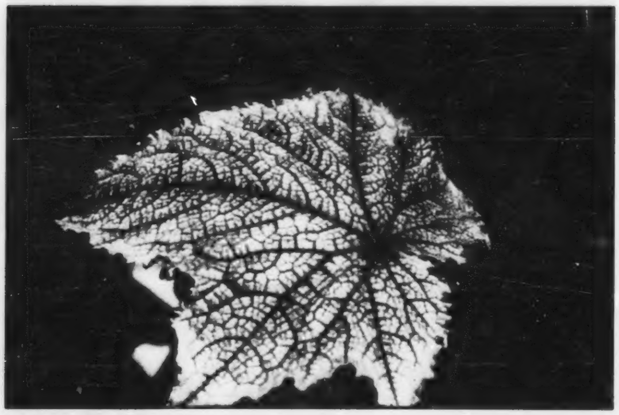


PLATE 48. Iron deficiency

PLATE 49. Botrytis

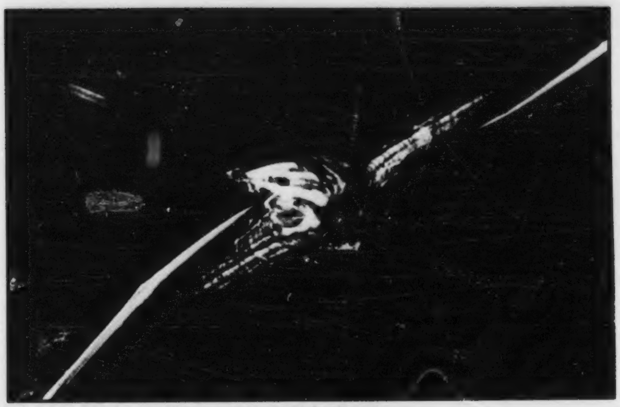


PLATE 50. Fusarium stem and fruit rot

PLATE 51. Fusarium stem and fruit rot

PLATE 52. Powdery mildew

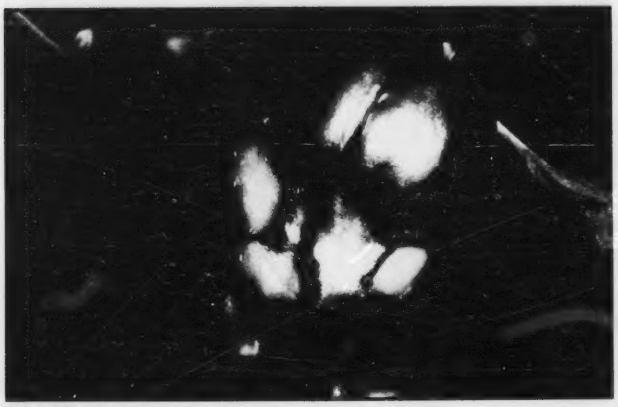


PLATE 53. Blossom end rot

PLATE 54. Fruit cracking due to internal growth

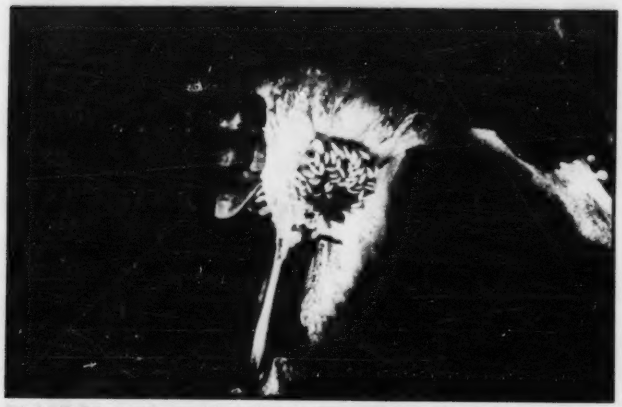


PLATE 55. Fruit cracking due to internal growth (cross section)

PLATE 56. Manganese deficiency

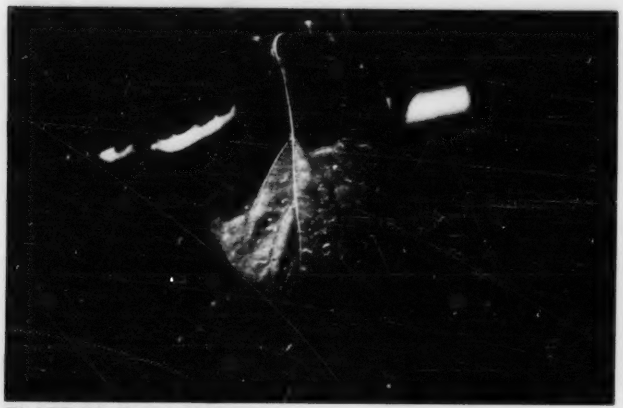


PLATE 57. Boron deficiency

PLATE 58. Western flower thrips and echinothrips

PLATE 59. Thrips damage to fruit, oviposition damage

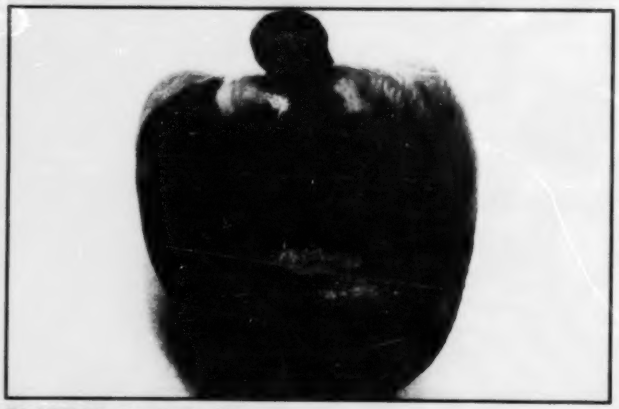


PLATE 60. Spotted wilt virus

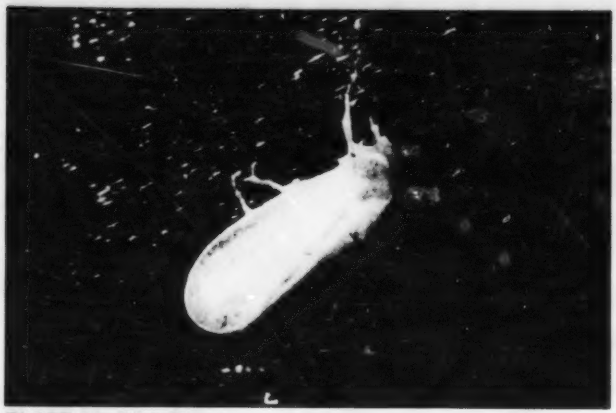


PLATE 61. Whiteflies

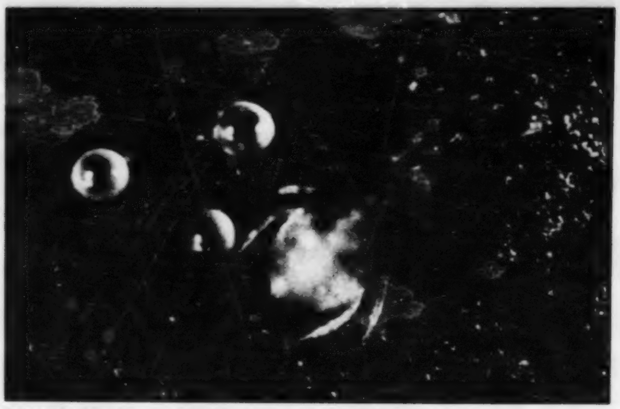


PLATE 62. Two-spotted spider mite with eggs

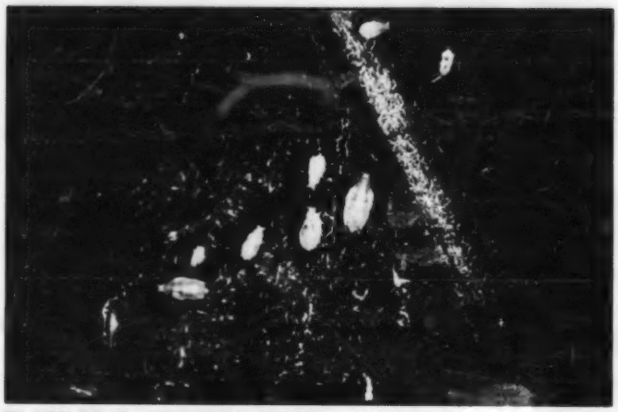


PLATE 63. Green peach aphids

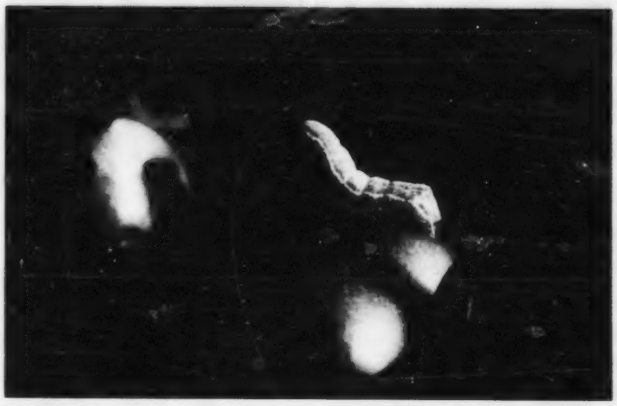


PLATE 64. Cabbage loopers

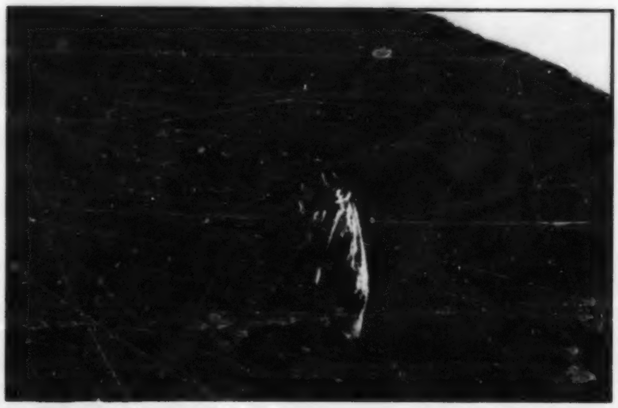


PLATE 65. Lygus bug

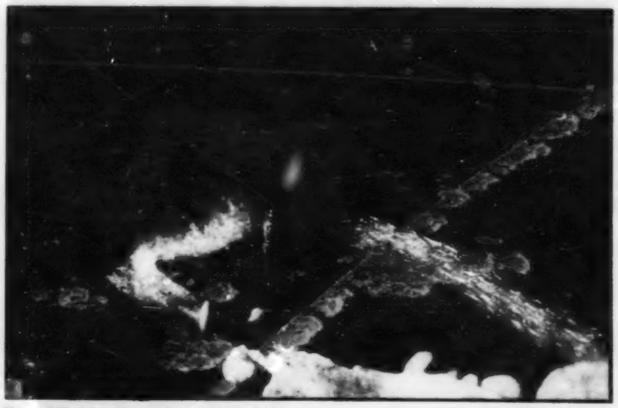


PLATE 66. Europen corn borer

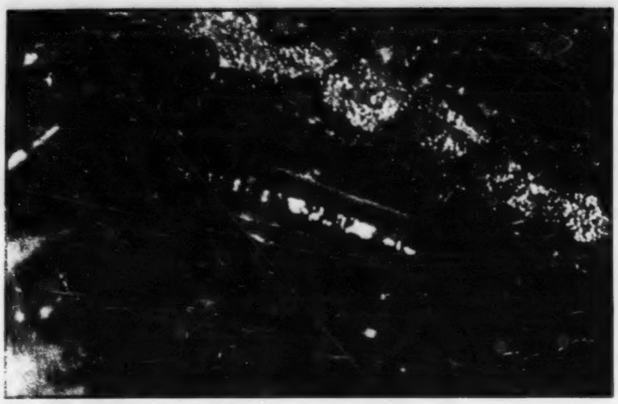


PLATE 67. Fungus gnats

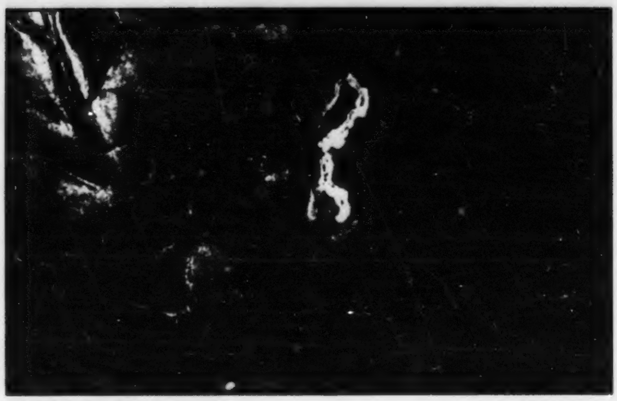


PLATE 68. Leafminers

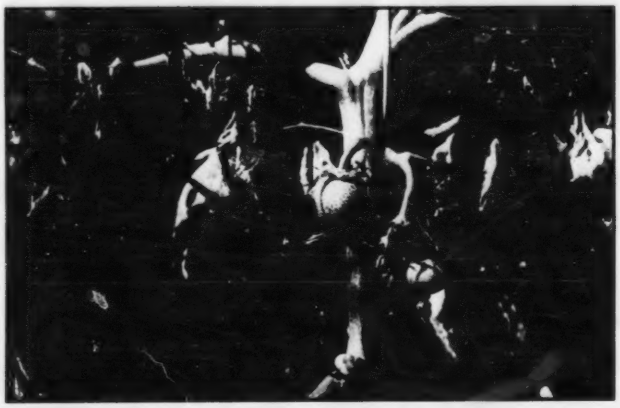


PLATE 69. Tomato russet mite damage on stem

PLATE 70. Tomato pin worm

PLATE 71. Close up of larvae

PLATE 72. Fruit damage caused by tomato pinworm

Emergency and First-Aid Procedures for Pesticide Poisoning

- Become familiar with the chemicals you are using. Keep a list of common names in case of accidents or emergencies. Common names are written on product labels and are cross-referenced in this publication. More extensive first-aid information is on product Material Safety Data Sheets (MSDS). These sheets are posted on company Web sites or are available from the farm supply centre where the chemical was purchased.
- If a pesticide comes in contact with the skin or is spilled on clothing, remove the clothing and wash the skin thoroughly with soap and warm water.
- If pesticide comes in contact with the eyes, rinse them continuously with clean water for 15 minutes. Repeat.
- If you suspect poisoning from exposure to a pesticide by swallowing, inhalation, or contact with skin or eyes, read the label on the pesticide container. Carry out the first-aid treatment suggested. Emergency phone numbers are listed on all product labels.
- **Immediately after first-aid treatment, wrap the patient in a coat or blanket and rush him/her to the nearest hospital. Take the list of chemical common names with you and identify the ones being used.**
- **If a person is unconscious, or lapses into unconsciousness, call an ambulance immediately.**
- **Emergency advice on pesticide poisoning is available from the Regional Poison Information Centres at:**

  Toronto 1-800-268-9017 Ottawa (bilingual) 1-800-267-1373
- **Those needing hearing assistance should call: 1-416-597-0215 (TTY)**
  Emergency telephone numbers are listed at the front of each
  Bell telephone directory.

  Fill in the following:

  My Local Poison Information Centre Telephone Number is:

  ______-________________________________

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A complete listing of all OMAFRA products and services, and order forms, are available on the web site. Orders can be faxed to (519) 826-3633 or mailed to Government Information Centre, OMAFRA, 1 Stone Road West, Guelph, ON N1G 4Y2

Published by the Ministry of Agriculture, Food and Rural Affairs
© Queen's Printer for Ontario, 2001
Toronto, Canada
ISSN 1492-6601
RV 04-01-3M